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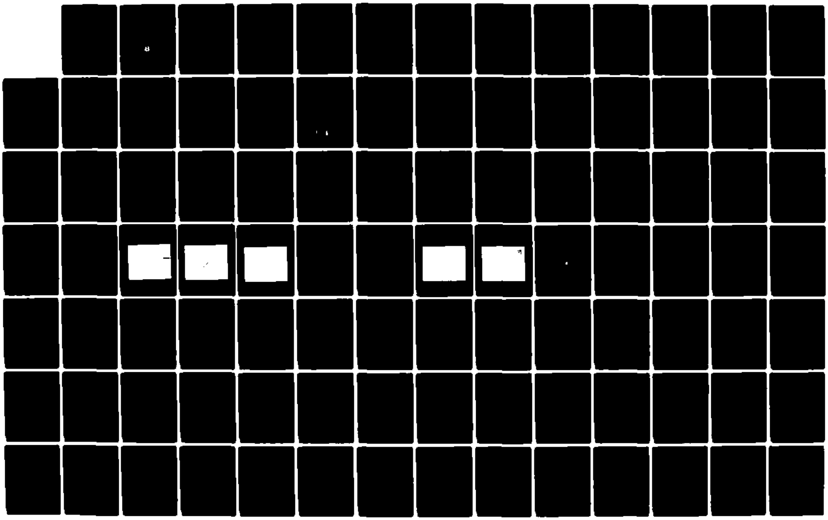

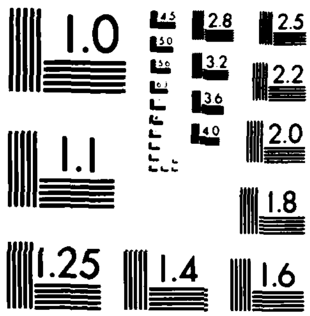

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USE OF PROTOTYPING FOR MAN-MACHINE INTERFACE REQUIREMENTS DEFINITION ON THE AWDS PROGRAM

By
CARL W. BENKLEY

AUGUST 1984

Prepared for

DEPUTY COMMANDER FOR INTELLIGENCE, C^{3}CM AND SUPPORT SYSTEMS
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This paper describes how prototyping was used as an aid in defining man-machine interface requirements for the Automated Weather Distribution System (AWDS). Ways in which man-machine interface prototyping can be used on system acquisition programs in general are also discussed.

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11. Interface Requirements Definition on the AWDS Program

EXECUTIVE SUMMARY

A prototyping study was carried out to investigate key elements of the man-machine interface (MMI) for the Automated Weather Distribution System (AWDS). The study was intended to provide MITRE with an evaluation tool for key elements of the design process, as well as to provide the AWDS contractor with data as a constructive guide for his MMI design.

The study focused on: 1) prototyping three candidate MMI models (command line syntax; prompted entry; menu-driven entry) for graphic processing; and 2) identifying methods by which the amount of displayed graphic information can be maximized without sacrificing clarity of presentation.

The menu-driven MMI model is recommended for AWDS graphic processing, owing to the numerous permutations of commands and arguments that must be accounted for, and the need to provide on-the-job training for the user. The menu-driven interface, a computer-initiated dialogue, is better than the two others for guiding the user through the input process. Our findings, nevertheless, showed that menu-driven input speed must be accelerated to better serve the experienced user. This could be achieved by establishing a concise relationship between a minimum set of necessary retrieval keys and fields in the AWDS "product identifier," a data set naming convention that consists of eight fields (with an average of nearly 100 possible entries per field), and a date-time group.

Because AWDS graphic monitors will not have the resolution traditionally allowed by facsimile machines and hand-drawn analyses, care must be taken to maximize display informational content. Critical resolution drivers are weather symbols (such as rain, snow, and thunderstorms), and parameter plots (symbolic depictions of the weather at observing stations). Display (font) sizes should be limited to 11 x 11 for weather symbols, and 44 x 29 for parameter plots.

ACKNOWLEDGEMENTS

This study could not have been carried out without the valuable computer program development efforts of K. M. Ledger, D. B. Lund, and L. C. Record. Their efforts are greatly appreciated. D. B. Lund, with assistance from E. H. LeClair and C. D. G. Markey, was also responsible for AGDS installation and maintenance. I am grateful to M. T. Drozd and K. C. Heyda for their candid and incisive reviews of draft versions of the manuscript. Thanks also to L. C. Nocca for the beautiful photographs. Finally, the skillful typing and editing of this manuscript by J. E. Lavery are greatly appreciated.

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1.0 INTRODUCTION

The man-machine interface (MMI) is a critical area in the development of on-line information and C^3I systems - users will judge the entire system based on their experience with the MMI. While the importance of developing a good MMI is clear, the approach to MMI requirements definition in system acquisition programs is not. High-level requirements for the MMI, as for any system software, are needed in the System Specification. Without these specifications, the contractor will lack the guidelines to approach MMI design. An ongoing MITRE study [SMIT83a] is looking at ways to strengthen MMI contractual mechanisms. Smith's report proposes approaches to Statement of Work (SOW) tasking, stipulation of deliverable data items, and generation of system specifications. In order to generate an effective set of specifications, however, an MMI model should first be established in at least a high-level conceptual sense. This paper explores one approach to the development of such a model - prototyping and evaluation of candidate designs. The study focuses on the MMI to the graphic processing component of the Automated Weather Distribution System (AWDS).

The mission of AWDS is to automate Air Force Base Weather Station weather analysis and briefing operations. MITRE's role encompasses technical assistance to the AWDS Program Office in the areas of:

(1) Preparation of the System Specification;

(2) Technical evaluation of offerors' proposals; and

(3) Monitoring of the contractor throughout the full-scale engineering development effort.

The AWDS contract was awarded in March 1984, the same month in which this report was issued.

The simulation studies described in this paper were performed using the AWDS Graphic Development System (AGDS), a set of processors and peripherals that were configured to emulate the AWDS Base Weather Station (BWS) Functional Area (FA) described in Section 3.0.

The use of prototyping for synthesizing MMI requirements should be considered for systems that are expected to have an intensive user-system interface. Thus, this paper tries to highlight aspects of the study effort that are relevant to MMI design in general. Much of the text (especially Sections 6.0 and 7.0) addresses specific AWDS-related details, but the conceptual investigatory strategy should be of general interest. Section 8.0 includes a general set of recommendations for MMI design support for all systems. The material in the Appendices is of interest only to those who are well-acquainted with AWDS.

2.0 BACKGROUND

Graphic processing, especially interactive graphic processing, is highly flexible, with an almost endless variety of methods for structuring man-machine dialogues. These methods range from simple command sequences to elaborate menu hierarchies, and each can include various levels of sophistication in the use of prompting, help, user feedback, and error recovery mechanisms. During the past few years, with the evolution of the personal computer and CAD/CAM systems, system designers have become aware that computer software must be easily usable by the non-programmer. Attention is being focused on human factors and ergonomics, and there has been a concomitant evolution in MMI design philosophies. As evidenced by newly-developed systems, traditional methods of man-computer dialogue, such as keyboard interaction, may be losing favor. Designers should be sensitive to contemporary design philosophies as candidates for on-line systems. System usability must be a highly visible design criteria, because even if all requirements are successfully implemented, a system may be considered a failure if it is too difficult to use.

The MMI should be a highly visible part of the system requirements definition phase in order to achieve the goals proposed by Smith [SMIT83a]. Suggested guidelines for use of prototyping in support of MMI requirements definition and System Specification preparation are described in Section 8.2.1. When the MMI cannot be analyzed in detail during these early program phases, such as was the case on AWDS, then the goals of a prototyping study must be directed toward the contract monitoring phase. The AGDS study itself was carried out in the time period between Request for Proposal (RFP) release and contract award. The specific goals of the study were:

(1) To explore the feasibility of various candidate designs for graphic processing;

(2) To provide a setting in which the user (Air Weather Service (AWS) and Air Force Communications Command (AFCC)) can critique the candidate designs and help select preferred approaches. It is hoped that this information can be provided to the contractor early in the contract, such as at System Requirements Review (SRR), to assist him during the definition of graphic processing designs;

(3) To identify and resolve problems with the System Specification, (including the Interface Control Drawing (ICD)) and actual candidate design approaches before they are encountered by the contractor; and

(4) To develop a set of tools that can eventually be applied to hands-on evaluation of contractor-proposed design approaches.

Two areas of AWDS graphic processing were selected for detailed study:

(1) Graphic Display Presentation - The study of methods for optimizing the use of display resources such as resolution and color. The incentive for this effort is that AWDS graphic display monitors can't provide the high resolution traditionally expected from facsimile machines and hand-drawn analyses.

(2) Graphic Man-Machine Interface - The study of possible logical interaction patterns and their mapping to physical input devices. The incentive for this effort is that, without active participation by the users or a designated technical support team, the contractor might have to select a design approach without the benefit of a task analysis or an understanding of operational requirements.

The study plan for each area is described in Section 5.0.

3.0 SYSTEM CONFIGURATIONS

The mission of the AWDS system is to update Air Force Base Weather Station (BWS) facilities and Notice to Airmen (NOTAM) facilities from an era of manual, labor-intensive operations to an era of automated, modernized stations, where the application of available computer, display, and communications technologies will provide more efficient use of resources and more timely responses to operational needs. AWDS will be deployed at Air Force and Army bases worldwide and will be serviced by two communications networks. A block diagram of AWDS appears in Figure 1.

The Base Weather Station (BWS) Functional Area (FA) (or the functionally-equivalent Staff Weather Officer/Wing Weather Officer (SWO/WWO) functional area) is the nerve center for weather forecasting activities in AWDS. The mission of the BWS is to prepare forecasts, warnings, and briefings for weather-sensitive operations. The BWS encompasses all the graphic processing capabilities required for AWDS, including:

(1) Display of externally-generated vector graphic and raster scan "products" (such as large-scale weather charts); and

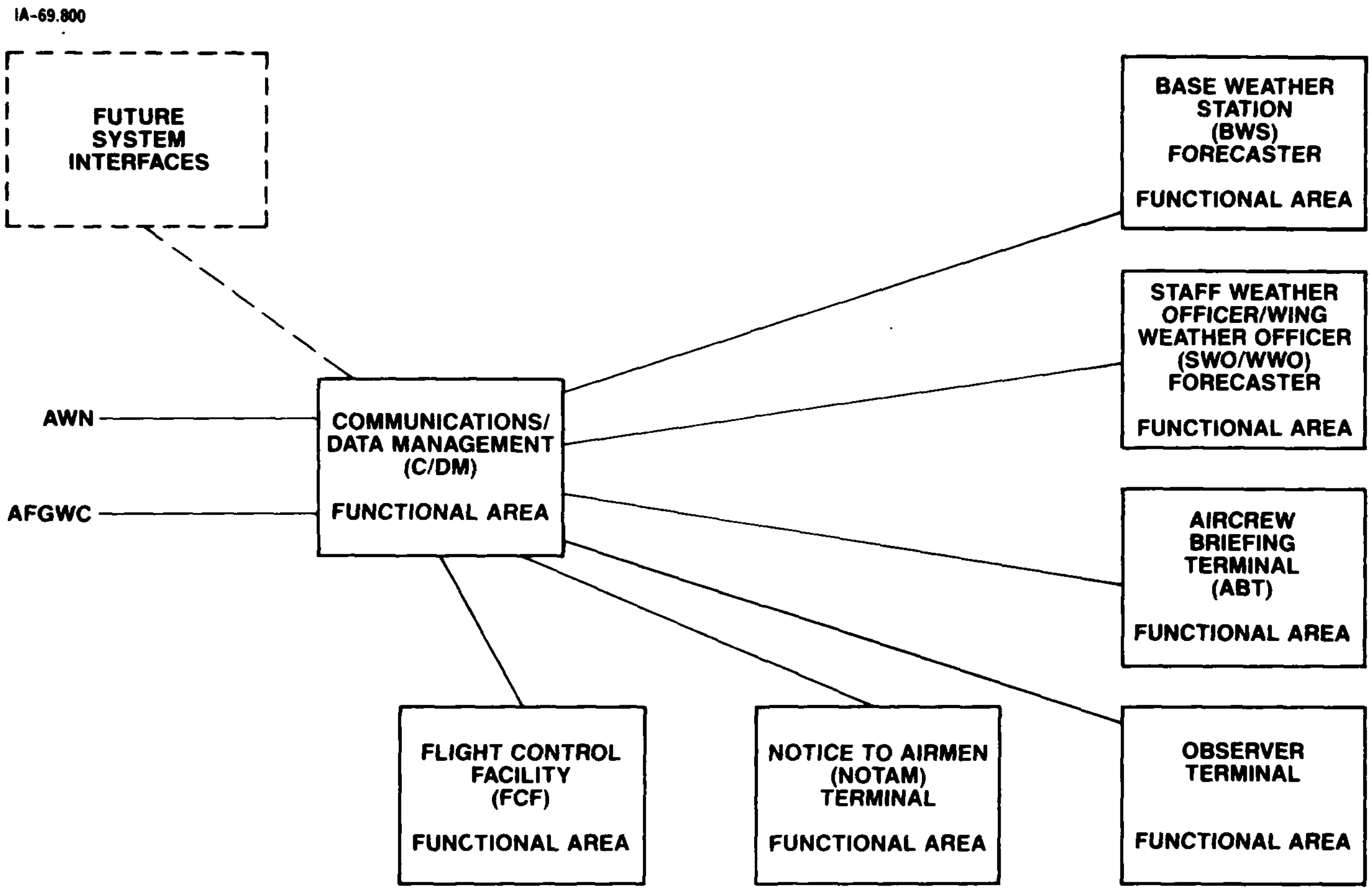
(2) Generation and display of locally-generated "composite" graphic products (probably in vector form), such as regional-scale weather charts, through any combination of the following functions:

   (a) Overlaying two or more vector graphic or raster scan products;

   (b) Exercising a vector graphic product generation function (such as isoplething) on raw weather data that is contained in Formatted Binary Data (FBD) or Uniform Gridded Data Field (UGDF) products; and

   (c) Adding or modifying vector graphic product information using the graphic interaction function.

The AWDS System Specification [OCR-AWDS-01] does not dictate a complete hardware configuration for the BWS, although it does specify the following minimum requirements:



LEGEND AWN: AUTOMATED WEATHER NETWORK
AFGWC: AIR FORCE GLOBAL WEATHER CENTRAL

Figure 1. AWDS Block Diagram

(1) Two 512 x 512 (nominal), eight-color graphic display monitors;

(2) One 24-line-by-80-column alphanumeric terminal;

(3) One keyboard;

(4) One graphic tablet; and

(5) One graphic/alphanumeric hardcopy device (could be shared with other functional areas).

The hardware configuration selected for the AGDS (see Figure 2) emulates the BWS configuration for a distributed AWDS architecture. We opted, however, for one high resolution graphic display monitor rather than two medium resolution monitors because we wanted to:

(1) Emulate two physical 512 x 512 monitors using two 512 x 512 logical viewports; and

(2) See whether the additional informational content displayable on a higher resolution monitor would be a significant aid to various operational tasks.

The AGDS configuration includes three alphanumeric terminals for the support of program development in a multiple-user environment. The nine-track tape drive and the floppy disk drive were included for Winchester disk backup, and for information transfer with other systems. A graphic hardcopy capability does not currently exist on the AGDS.

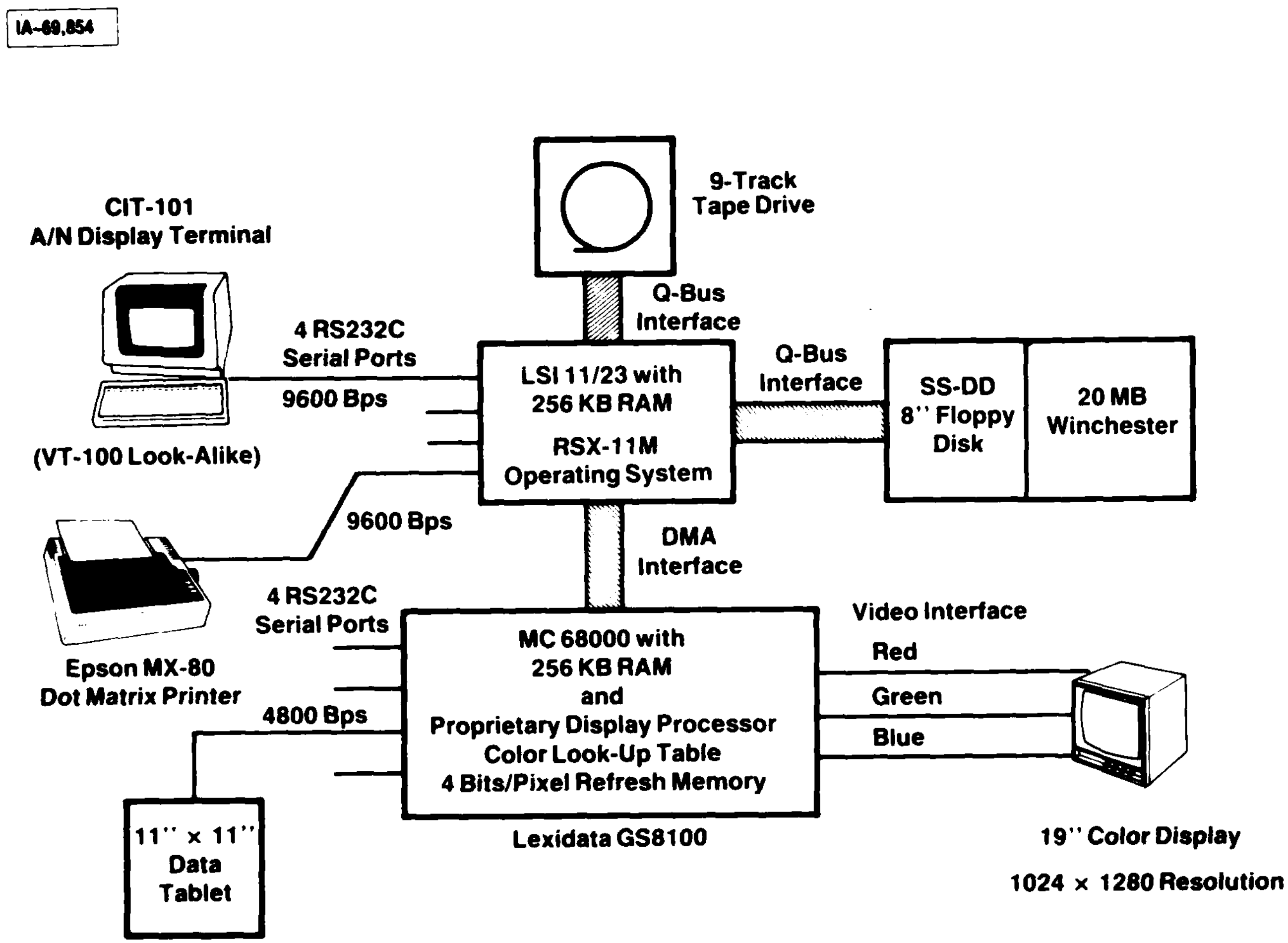


Figure 2. AGDS Configuration

4.0 MAN-MACHINE INTERFACE CONSIDERATIONS

MMI design requires the designer to pay attention to human factors and ergonomics. Most investigators would agree that the field of MMI design, particularly for graphics, is in its youth; while much is known, MMI design is still more of an art than a science. There are a variety of guidelines for the good practice design of MMI, but one cannot show deterministically that a particular MMI approach is best for a given type of system or application. A comprehensive discussion of MMI design concepts is beyond the scope of this paper; for an in-depth treatment, "Fundamentals of Interactive Computer Graphics" by J. D. Foley and A. Van Dam [FOLE82] is recommended.

The purpose of this section is to introduce a few key MMI design principles, and to discuss special considerations relating to AWDS. In addition, this section surveys other Automated Weather Information Systems (AWIS), and notes points of interest relating to AWDS MMI design.

4.1 General Considerations

According to Foley and Van Dam, the most important guidelines for the design of interactive programs are:

"(1) Provide simple, consistent interaction sequences;

(2) Do not overload the user with too many different options and styles for communicating with the program;

(3) Prompt the user at each stage of the interaction (but allow the more experienced user to bypass prompts);

(4) Give appropriate feedback to the user; and

(5) Allow graceful recovery from mistakes."

Another key element to consider is the experience of the system user. Foley and Van Dam recognize three experience levels: "novice users, who are just learning the basic concepts and mechanics of the system; intermediate users, who have learned to do some productive work and are now building proficiency and learning additional system capabilities; and experienced users, who are proficient in all or most system aspects and who know all of the system capabilities (some systems have so many capabilities that users are experienced only with certain sets of frequently used capabilities)." Understandably, novice users are more comfortable with systems that guide them through the intricacies of input, while the experienced users are better served by systems that are optimized for speed of use. It is a challenging task to accommodate the needs of all three user groups. Often, an effective compromise is an MMI that incorporates prompting and help facilities that can be used by the novice, and bypassed (possibly in incremental steps) as the user gains experience.

The determining factor in the success of MMI design is often not the ability of the system designers, but the development costs involved - a dichotomy of ease of implementation versus ease of use. Ideally, the development of the MMI is carried out in a logical manner, as follows:

(1) Develop an understanding of the problem and the prospective users;

(2) Develop an operational concept for the system;

(3) Design the MMI in a top-down fashion;

(4) Implement (code) MMI functions; and

(5) Refine the MMI through a test and evaluation procedure involving the prospective user.

When budget or schedule constraints exert pressure to get the system running as soon as possible, designers may not allot sufficient time to develop a thoughtful design. The resulting design may be inadequately detailed and be fraught with internal inconsistencies; the final system itself can be deplorable, or at least very frustrating to use.

4.2 AWDS-Specific Considerations

According to the System Specification, AWDS equipment shall be designed for operation by enlisted military technicians of skill level five. It takes the enlisted weather technician three or four years to attain level-five proficiency. He or she must:

(1) Complete a six-month course in weather observing techniques and practices;

(2) Obtain two or three years of experience as a weather observer;

(3) Complete a six-month course in weather forecasting; and

(4) Finally, demonstrate level-five proficiency on the job (often just a formality for one who has completed the forecasting course).

Air Force Specialty Training Standard (STS) 251X0 describes the tasks, knowledge, and study references necessary for airmen to perform duties in the Weather Ladder of the Airman Weather Career Field. For weather analysis, a key function that will require an intensive user-system dialogue when transferred to AWDS, the STS shows that the weather technician can be qualified at level five with only a "nomenclature" "Task Knowledge Level" proficiency (nomenclature is the lowest of four levels), and no (not even an "extremely limited") "Task Performance Level" proficiency. The same skill ratings also apply for weather forecasting and briefing. The STS does not currently include proficiency standards for computer usage skills, although this must change in the AWDS era, when AWDS equipment will be used in the training courses. For weather technicians already in the field when AWDS is deployed, a two- or three-week training course will be provided.

The profile that emerges for the novice user is that of a person who will be learning how to do his job at the same time he or she is learning how to use the system. This user group will need an easy-to-use system.

The needs of the user after becoming experienced with AWDS are not as clear. The aggregate complexity of AWDS may prevent the expert from becoming proficient for all but a subset of commonly used commands. As discussed further in Section 6.1.3, there are more than 100 separate ordinal combinations of commands and arguments in the graphic processing area alone, and an almost endless number of possible permutations of command/argument values. The complexity stems from the fact that AWDS will likely carry a running inventory of 2775 individual products, many of which can be used as input data sets for a number of different applications functions. It appears, therefore, that even the experienced user would frequently make use of available support features.

4.3 Survey of Other Automated Weather Information Systems

There are Automated Weather Information Systems (AWIS) in operation today that bear functional similarities to AWDS. As an aid to requirements definition, the AWDS team studied and even visited many of these systems. We were interested in learning about users' reactions to the particular man-machine interfaces employed. Table 1 lists some of the more noteworthy AWIS studied, their missions, dates of deployment (or initial operation), and the MMI styles used. The earlier systems relied exclusively on command line syntax input. Users of the Man-Computer Interactive Data Access System (McIDAS) (who are generally of high experience level) felt that the command line syntax is preferable because it is fast; but in contrast, users of the Automation of Field Operations and Services (AFOS) at the Boston National Weather Service (NWS) Forecast Office were observed to have difficulty performing non-commonly used functions.

The Prototype Regional Observing and Forecasting Service (PROFS) is the most influential system in operation today because its goal has been to develop and operationally test a prototype system that could replace AFOS in NWS offices by the early 1990's. The PROFS program has supported a full-time MMI design team, and has actively solicited experimentation with the system by personnel from all sectors of the meteorological community. Users have reacted favorably to the menu-driven interface structure (which is mapped to a touch panel overlaying a graphic monitor dedicated to display of menus). The PROFS MMI shields the user from low-level data set retrieval details, enabling the user to rapidly produce a display through fingertip selection of familiar weather parameters. While the physical implementation of the PROFS MMI may not be cost-effective, anyone associated with AWDS cannot overlook the widespread enthusiasm with which the PROFS menu-driven MMI has been embraced. PROFS points out a clear direction for future AWIS MMI.

Table 1

Selected Automated Weather Information Systems and *Man-Machine* Interface Styles

System	Date Deployed or Operational	Sponsor	Mission	MMI Style
McIDAS	Early 1970's	University of Wisconsin; Air Force Geophysics Laboratory (AFGL)	Research and Development	Command Line Syntax
AFOS	Late 1970's	National Weather Service (NWS)	Automation of Forecast Offices	Command Line Syntax
Penn State	Late 1970's	Pennsylvania State University	Research and Development; Teaching	Command Line Syntax
Colorgraphic	1980	Colorgraphic Systems, Inc.	Commercial (Designed for Television Weather Programs)	Prompted Entry
PROFS	Early 1980's	National Oceanic and Atmospheric Administration (NOAA)	Research and Development; Workstation Prototyping	Menu-Driven Entry

5.0 THE AGDS STUDY PLAN

The AGDS study plan was prepared in January, 1983, and has been closely followed throughout the effort. The study plan outlined a set of tasks to be performed under the graphic display presentation and graphic MMI study areas. The original study plan appears in Appendix A.

5.1 Man-Machine Interface Study Plan

The study plan for the MMI area identified three conceptual models that could be considered as candidates for the graphic MMI:

(1) A command line syntax structure;

(2) A prompted entry structure; and

(3) A menu-driven structure.

All three structures have been used in many systems, and do not appear to introduce any conflicts with the System Specification. These structures are described in detail in Section 6.1.3.

One also needs to study how the designs should map to logical and physical input devices. In AWDS, the physical input devices include, as a minimum, a keyboard and a graphic tablet. Ergonomic considerations favor the use of a single input device for control of a given function or family of functions, but this is not always possible if "natural" mappings are exploited (e.g., the mapping of text string input to a physical keyboard).

Although the MMI study has since been expanded to include all AWDS graphic processing functions, the original study plan focused on the interfaces to two key sets of functions: the horizontal analysis composite product functions and the zoom and graphic interaction functions. The horizontal analysis composite product functions comprise a set of tools (such as display, isopleth, plot, and streamline) used to create analyses of the weather on background maps. The graphic interaction functions provide an interactive capability to add, delete, relocate, and highlight features on graphic products. The zoom functions allow the user to magnify selected areas of products.

Details of the graphic MMI study are described in Section 6.0.

5.2 Graphic Display Presentation Study Plan

The study plan for graphic display presentation identified two tasks:

(1) The study of graphic depictions of various weather symbology; and

(2) The study of data density and product complexity levels for various graphic products.

Because of the limited display screen resolution specified for AWDS, care must be taken to maximize informational content. Insufficient informational content makes it difficult for the weather forecaster to analyze or mentally integrate weather patterns. The goal of the first task was to study how weather symbology can be displayed in a manner that is legible, but economical in terms of display size. Three types of weather symbology studied are:

(1) Meteorological symbols - pixel pattern representations of weather symbols such as rain, snow, and thunderstorms;

(2) Parameter plot models - organized arrangements of meteorological symbols and alphanumeric characters that depict the weather at observation stations; and

(3) Symbolic lines - polylineal or polygonal weather features such as weather fronts and cloud and precipitation area outlines.

The study plan for data density and product complexity levels for graphic products was aimed at determining how much information (e.g., number of parameter plots, number of isopleths, amount of map background detail) could be clearly displayed on both medium and high resolution graphic monitors. The results of this task provide guidelines for the design of functions used to create locally-generated products, and suggest limits for the complexity of externally-generated products.

Details of the graphic display presentation study are described in Section 7.0.

6.0 MAN-MACHINE INTERFACE STUDY

This section describes the approach used to develop the three candidate man-machine interfaces, and points out their advantages and disadvantages. Design of the interfaces to the zoom and graphic interaction functions is discussed separately. Implementation of selected functions is described in Section 6.4.

6.1 Design of Strawman Interfaces

The design of man-machine interfaces, as is the case with all software, should be approached in a top-down fashion. However, since the System Specification preceeded MMI conceptual model development, and not vice versa, a modified progression of design steps was followed:

(1) Prepare a checklist of Specification requirements for operator interaction, and identify those relating to graphic processing;

(2) Develop a strawman hierarchy of MMI-related graphic processing functions;

(3) Formulate candidate conceptual MMI models (e.g., command line syntax);

(4) For each model, postulate logical interaction patterns, define logical input devices and the mapping of logical input devices to physical input devices; and

(5) Include mechanisms for prompting, help, user feedback, and error recovery.

The first two steps extract and logically organize functional requirements, and the third step defines the conceptual MMI models. Steps 4 and 5 define the semantic design (operations performed and their effects), the syntactic design (user's logical actions and their effects), and the lexical design (binding of language tokens to physical actions).

6.1.1 Design Step 1

In the first step, AWDS MMI requirements were identified and categorized according to three main types: alphanumeric, graphic, and control. To facilitate this task, the following definitions were adopted:

(1) The alphanumeric category shall apply to those actions necessary for the creation, modification, acquisition, and disposition of alphanumeric products and computation results;

(2) The graphic category shall apply to those actions necessary for the creation, modification, acquisition, and disposition of graphic products; and

(3) The control category shall include computer operations, login/logout procedures, and management of control tables.

Appendix B contains the complete list of Specification requirements for MMI and their categorization.

6.1.2 Design Step 2

In the second step of the process, a strawman hierarchy was developed for all MMI-related graphic functions. The hierarchy defines all inputs needed for complete specification of a function to be performed and a data set on which to perform that function. For AWDS, operator inputs are of the following types:

(1) Commands - for example, display and isopleth;

(2) Data Set Selection - specification of sufficient information for unique retrieval of a product by its eight-field product identifier structure and valid time (as discussed in the AWDS Interface Control Drawing (ICD));

(3) Display Control - identification of the monitor on which the display will appear; and

(4) Other Arguments - arguments, often optional, which control how the function is performed or how the display will appear (for example, plot model selection or data override information).

The second type of operator input, data set selection, will be examined in detail in Section 8.1.2. To ensure that every product could be uniquely identified and retrieved, it was assumed that each component of the product identifier must be matched to an equivalent retrieval key. The only exceptions permitted were: 1) omission of a retrieval key for the File Indicator (F) for all products, reflecting a general understanding that it is not necessary for retrieval; and 2) elimination of retrieval keys for the "ii" and "EE" fields for Formatted Binary Data (FBD) products. (For FBD products, these fields describe a reporting station grouping scheme that is not helpful for retrieval of all weather observations within a given geographical area.)

The complete strawman hierarchy is presented in Appendix C. Although the hierarchy appears to represent a hierarchy of menus, the hierarchy is independent of any logical or physical MMI implementation. The "menu" entries represent possible or allowable input values, not methods for selecting them. Appendix C also includes a set of notes and assumptions relating to the hierarchy. Many of these notes describe ways in which specific MMI requirements can fit within the general hierarchical framework. These methods should be given consideration for actual implementation in AWDS.

6.1.3 Design Step 3

In the third step, three candidate models were defined:

(1) A command line syntax structure;

(2) A prompted entry structure; and

(3) A menu-driven structure.

The command line syntax is categorized as a user-initiated dialogue because the user controls the input and selects options without being presented an explicit set of alternatives. The prompted entry and menu-driven structures are categorized as computer-initiated dialogues because the system takes the initiative in guiding the user through the input process.

The command line structure is based on input of a single-line string of text that includes the function and its associated arguments. The syntax is of the form:

command/arg. 1/arg. 2/.../arg. n

The command line structure is rather inflexible and requires the operator to remember the correct order of input. For AWDS, this could cause confusion for anyone but the most experienced user because the type of inputs and order of inputs often vary depending on inputs previously entered. According to the hierarchy in Appendix C, there are more than 100 separate paths through the hierarchy for AWDS graphic functions alone. This, coupled with the need to know the set of allowable values (and allowable abbreviations of values) of each input, imposes a formidable memorization problem. Normally, the entire command line syntax is input before the command is parsed by the system, although a help function can be accommodated that when invoked, will parse the portion of the command already entered, and will provide help for the next required input in the command line syntax.

The prompted entry structure removes the burden of memorizing the order of input by guiding the operator through a decision tree input process. It is of the form:

Command? [operator response]

Argument 1? [operator response]

Argument 2? [operator response]

.
.
.

Argument n? [operator response]

The structure leads the operator along a unique path through the hierarchy and prompts the user for parameter input at each level. The prompted entry is amenable to the incorporation of various help features such as listings of allowable input values (and abbreviations), required input formats, and default values.

The menu-driven structure also implicitly incorporates order of parameter input by leading the operator through a series of menus that list allowable values for each input. The menus are of the form:

(page 1)	(page 2)		(page n)
<u>Command</u>	<u>Argument 1</u>		<u>Argument n-1</u>
Command 1	Value 1		Value 1
Command 2	Value 2	● ● ●	Value 2
.	.		.
.	.		.
.	.		.
Command m	Value m		Value m

The list of allowable values for each argument could include all conceivable possibilities, or only those possibilities that, given the values already input, will lead to the identification of a meaningful function and a meaningful data set on which to perform that function. Implementation of the latter option eliminates the possibility of erroneous or meaningless input. The implementation of the menu-driven interface on the AGDS uses a combination of the two methods: all possible values are listed, and "meaningful" values are highlighted. (Since the AGDS is not intended to be a mini-AWDS, very little of the full AWDS functionality is available, and few values are highlighted.)

As a specific example of the three MMI structures, assume that the operator wants to isopleth surface pressure using hourly surface observations, as described in Table 2. The resulting isobars are overlayed on a background map (see Figures 3-5 for examples). The implementation of this function is given in Table 3 for each interface structure. Note that for the command line syntax and prompted entry structures, argument abbreviations can be used, if known.

6.1.4 Design Step 4

The fourth step in the top-down design of candidate man-machine interfaces involves formulating logical interaction patterns, identifying a set of logical input devices for interacting with MMI software, and then mapping these logical input devices to physical input devices. For this study, we considered the set of logical input devices identified by the Graphical Kernel System (GKS), a device-independent graphic programming standard supported by the International Standards Organization (ISO) and the American National Standards Institute (ANSI). Table 4 describes the general purpose of each logical device, and identifies appropriate ways in which the devices can be used in operation with AWDS functional requirements. Each of the logical devices is then mapped to one of the physical input devices required by the System Specification: the alphanumeric keyboard or the graphic tablet. Finally, recognizing the importance of user feedback in human factors design, the Table identifies the appropriate physical output (echo) device.

Following the relationships established in the Table, the candidate man-machine interfaces for command line entry and prompted entry, which require intensive text string input, have primarily been mapped to the alphanumeric keyboard and monitor. The menu-driven interface, which relies on picking of menu entries, has primarily been mapped to the graphic tablet and monitor.

Table 2

Isopleth Function Example

Functional Type: Horizontal Analysis Composite Product Function

Function: Isopleth

Monitor: 1

Data Indicator: Formatted Binary Data

Data Designator: Hourly Surface Reports

Surface Parameter: Pressure

Valid Time: 1200 GMT Today

Isopleth Levels: Default

Data Override: No Override

Table 3

Three Implementations for the Isopleth Function Example

1. Command Line Syntax Implementation

```
ISOPLETH/1/FORMATTED BINARY/SURFACE/PRESSURE/1200,TODAY///
```

2. Prompted Entry Implementation

```
FUNCTION?

MONITOR (1, 2)?

DATA INDICATOR?

DATA DESIGNATOR?

SURFACE PARAMETER?

VALID TIME?

ISOPLETH LEVELS?

DATA OVERRIDE?
```

Table 3 (continued)

3. Menu-Driven Implementation

Cycle through the following menus (from Appendix C) in order:

1.1

1.1.6

1.1.6.1

1.1.6.1.1

1.1.6.1.1.1

1.1.6.1.1.1.1

1.1.6.1.1.1.1.1

Return to Menu 1.1 upon completion.

Table 4

Mapping of Logical Input Devices to Physical Input Devices

Logical Input Device	General Purpose	Specific AWDS Purpose(s)	Physical Input Device(s)	Physical Echo (Output) Device(s)
Pick	Provides a segment name and a pick identifier associated with a particular primitive	1. Menu selection 2. Selection of graphic features for the graphic interaction function	Graphic tablet and stylus	Graphic monitor
String	Provides a character string	1. Text string input	Keyboard	Alphanumeric monitor
Choice	Provides an integer defining one of a set of choices	1. Programmable function keys 2. Functional control	1. Keyboard (programmable function keys) 2. Buttons on graphic tablet stylus	1. See Note 2. Graphic monitor
Locator	Provides a position in World Coordinates	1. Placing symbols and drawing symbolic lines (graphic interaction function)	Graphic tablet and stylus	Graphic monitor
Valuator	Provides a real number (scalar value)	None	-	-

Note: The physical echo could appear on either the alphanumeric or graphic monitor, or could be entirely suppressed if a very long function, or set of functions, is mapped to the function key.

There are exceptions to these relationships. The first exception, relating to the menu-driven interface, allows text string input from the alphanumeric keyboard when it cannot be avoided. An example is the key-in of a user-defined label by which a locally-generated product is subsequently stored. (Retrieval of a locally-generated product would, however, be driven from a menu of labels for available locally-generated products.) The second exception, relating to the command line syntax and prompted entry structures, concerns a few key functions, most notably the zoom and graphic interaction functions, which are graphically interactive by nature. The graphic interaction functions and zoom functions can be invoked by any of the three interface structures, but it is felt (and actually driven by the System Specification) that the mechanics for carrying out these functions naturally map to the pick and locator logical input devices and, hence, the graphic tablet physical input device. Thus, in the study of candidate interface structures, the zoom and graphic interaction functions are dealt with separately from the three candidate interfaces (See Section 6.3).

6.1.5 Design Step 5

The final step in the top-down design of candidate interfaces involves fine-tuning the designs to maximize their ease of use. Mechanisms for prompting, help, user feedback, and error recovery were considered for each candidate design. This area was given cursory attention because the goal of the study was to compare and contrast the high-level utility of each candidate design, not to dwell on low-level detailed implementations.

6.2 Comparison of the Three Interface Styles

Table 5 draws a comparison between the three interface structures. Evaluation of the speed of use criterion, comparing novice and experienced users, is based on our own judgement since we did not have the opportunity to test the designs on a candidate users group. It is expected that the menu-driven interface could be operated by both novice and experienced users with about equal proficiency. As discussed in Section 8.1.2, entry via the menu-driven interface could be accelerated if a concise relationship between product retrieval keys and product identifier fields was established. Input speeds for the novice versus experienced user are expected to rapidly diverge when the menu-driven interface style is replaced by either the command line syntax or prompted entry. For the experienced user, the command line syntax would be quicker to use than the menu-driven interface (for at least a commonly-used subset of the full functionality), but for the novice user, the command line syntax might be impossible to use.

Table 5

Comparison of the Three Candidate Man-Machine Interface Structures

	Command Line Syntax	Prompted Entry	Menu-Driven Entry
Speed of use (novice)	Very Slow	Slow	Moderate
Speed of use (expert)	Fast	Moderate	Moderate
Ease of implementation	Moderate	Moderate	Moderate
Contention for alphanumeric terminal	Moderate	High	Low
Error potential	High	Moderate	Low

Concerning ease of implementation, the time to implement the MMI for a given function was found to be largely independent of the interface style. The design effort involved in developing the graphic hierarchies in Appendix C applies equally to each model. Correspondingly, the same programming logic was implemented to instruct the system how to respond to operator-selected parameter values once parsed. The only differences - and they are minor - relate to implementing the MMI dialogue itself. The command line syntax does not require prompting, but command parsing is more complex because of the freer format of the command, and the need to recognize abbreviations of parameter value names. By comparison, graphic menus are straightforward to implement with a high-level subroutine package (e.g., GKS-based), and selection of parameter values is simple because it works by position designation, not by recognition of names or abbreviations. Thus, ease of implementation does not depend on the MMI model selected, but, in all cases, it is strongly (and inversely) influenced by the effort expended in developing ancillary features such as help, user feedback, and error recovery mechanisms.

The error potential criterion measures the susceptibility of each interface style to user input errors. The command line syntax is most prone to errors because it is sensitive to both erroneous parameter values and invalid order of input. The prompted entry is less susceptible because it removes the need to memorize order, but still leaves most of the burden of selection of valid values to the user. The menu-driven interface will be minimally error prone if menus are updated in real time to reflect those data sets currently available for the function being performed. Ease of error recovery is somewhat dependent on the sophistication of prompting and help facilities provided with the interface structure. For the command line syntax, bad parameter values may not be detected until input is complete and the command is parsed as a whole. Depending on the implementation, the user, at best, will be able to correct individual parameter values, and, at worst, will be forced to retype the entire command (and may not even be told what he did wrong). The prompted entry and menu-driven structures are more amenable to graceful error recovery because error checking (to any level of sophistication) can be performed following each parameter input. This feature also tends to simplify implementation.

Contention for the alphanumeric terminal will result when concurrent use by, or input for, graphic and alphanumeric functions is precluded. If graphic processing functions are controlled by the alphanumeric terminal, contention will result when, for example, the operator uses a full-screen alphanumeric form to enter information obtained by recalling and viewing a series of graphic products. Contention for the alphanumeric terminal could be minimized by partitioning the screen to include a small viewport for graphic-related input, but this might not be feasible for the prompted entry structure's more wordy question-and-answer dialogue.

6.3 Graphic Interaction Functions and Zoom Functions

As discussed earlier, the graphic interaction functions and zoom functions are interactive in nature. These functions may be invoked by any of the three candidate interface structures, but the lower level mechanics intrinsic to carrying out these functions are independent of the driving interface structure.

The graphic interaction functions and zoom functions are described as follows:

(1) Add Symbol - Add a selected weather symbol at a selected location;

(2) Add Symbolic Line - Draw a line in a selected line style (e.g., cold front);

(3) Add Character - Add a selected alphanumeric character at a selected location;

(4) Add Text String - Add a text string at a selected location;

(5) Delete Segment - Delete a selected graphic segment (e.g., symbolic line, station parameter plot) from the display;

(6) Highlight Segment - Highlight a selected graphic segment;

(7) Relocate Segment - Relocate (as by dragging) a segment on the display;

(8) Polygon Fill - Fill a selected polygon (e.g., a closed symbolic line) on the display;

(9) Zoom A - Magnify (by pixel replication) the display around a selected zoom centerpoint and permit roaming (if desired); and

(10) Zoom B - Magnify (without pixel replication) the display around a selected zoom centerpoint and increase the number of displayed station parameter plots. Roaming is not required.

One example of the use of these functions is weather frontal analysis, a task for which no dependable objective algorithm is available. The analyst is trained to position fronts accurately by examining parameter plots for all available surface reporting stations within the general vicinity of a given front, and recognizing signatures revealed by the simultaneous geographic variation of parameters such as temperature, dewpoint temperature, pressure, barometric tendency and characteristic, and wind direction. In AWDS, this task will be carried out using the Plot, Add Symbolic Line, and Zoom B functions.

Each graphic interaction function or zoom function could be implemented in a variety of different ways. Rather than explore an endless number of possibilities, the goal was to design, implement, and fine-tune a single procedure for each function. Care was taken to incorporate helpful design techniques, such as:

(1) Dragging - Allow the user to reposition a graphic segment with real-time display of its resultant motion;

(2) Software generation of line styles - When drawing a symbolic line, the user need only provide the line path. The software will subsequently redraw the line in the proper symbolic line style; and

(3) Partial line modification - Rather than forcing the user to delete and then redraw the entire line, the software allows the user to redraw only the portion of interest.

The strawman implementation of each function is described in Table 6. The Table describes each procedural step, identifies the appropriate logical input device, and describes how feedback is provided to the user following input. The pick, locator, and button logical devices were mapped to three physical buttons on the graphic tablet stylus (four are provided). The remaining button is used for an escape function, allowing the user to abort the current graphic interaction or zoom function, and return to the original processing state (i.e., no changes are accepted).

6.4 Implementation of AWDS Application Functions

There was no need to develop a "mini-AWDS" because the interfaces to all but intensively interactive functions can be studied without implementing the functions themselves. For various reasons, however, a few selected functions were implemented. These

Table 6

Implementation of the Graphic Interaction Functions and Zoom Functions

Function and Procedure	Logical Input Device (Table 4)	Echo Type (Feedback) Provided to User
Add Symbol		
Select symbol	See Note 1	See Note 1.
Place/drag symbol	Locator	Symbol is displayed at proper location during placement & dragging.
Terminate	Choice	See Note 2.
Add Symbolic Line		
Select symbolic line type	See Note 1	See Note 1.
Draw line	Locator	A solid line is displayed, echoing stylus path on tablet.
Terminate	Choice	Symbolic line is redrawn in proper line style (also see Note 2).
Add Character		
Select character, color, size, width	See Note 1	See Note 1.
Place/drag character	Locator	Character is displayed at proper location during placement & dragging.
Terminate	Choice	See Note 2.
Add Text String		
Input text string	String	Text string is displayed on alphanumeric terminal.
Place/drag text string	Locator	Text string is displayed at proper location during placement & dragging.
Terminate	Choice	See Note 2.
Delete Feature		
Pick feature	Pick	Feature is highlighted.
Delete feature & terminate	Choice	Feature is deleted from display (also see Note 2).
Highlight Feature		
Pick feature	Pick	Feature is highlighted.
Highlight feature	Choice	See Note 2.
Relocate Feature		
Pick feature	Pick	Feature is highlighted.
Drag feature	Locator	Feature is displayed at proper location during dragging.
Terminate	Choice	See Note 2.

Table 6 (Continued)

Function and Procedure	Logical Input Device (Table 4)	Echo Type (Feedback) Provided to User
Modify Symbolic Line		
Pick feature	Pick	Feature is highlighted.
Redraw selected portion of feature	Locator	Redrawn portion is displayed as a solid line (see Note 3).
Terminate	Choice	Redrawn portion is displayed in proper line style; replaced portion is deleted from the display (see Note 3).
Polygon-Fill Closed Symbolic Line		
Pick feature	Pick	Feature is highlighted.
Fill and terminate	Choice	Feature is filled (also see Note 2).
Zoom A		
Select zoom ratio	See Note 1	See Note 1.
Select zoom centerpoint	Locator	Product window (centered at selected centerpoint) is displayed at selected zoom ratio.
Move zoom centerpoint	Locator	Product window is dynamically repositioned.
Terminate	Choice	See Note 2.
Zoom B		
Select zoom ratio	See Note 1	See Note 1.
Select zoom centerpoint and terminate	Locator	Product window (centered at selected centerpoint) is displayed at selected zoom ratio.

Note 1: This uses the command line syntax, prompted entry, or menu-driven entry interface structure itself.

Note 2: Standard feedback includes prompting for next command (such as placing cursor back in menu area, given the menu-driven interface style).

Note 3: For most symbolic lines, the orientation of line style components (such as frontal pips) is dependent on the drawing path direction of the line. Symbolic lines are modified by redrawing the line between two selected points, p_1 and p_2, where *at least* one of the *points* must be on the line path. If p_1 and p_2 are both on the line path, p_2 must be further along the linepath from the origin than p_1. If only p_2 is on the line path, p_1 becomes the new line origin. If only p_1 is on the line path, p_2 becomes the new line terminus.

functions belong to two functional sets: the horizontal analysis composite product functions (display, plot, isopleth, streamline, etc.), and the graphic interaction and zoom functions. The two functional sets embody important complementary aspects of graphic processing and will receive heavy use in AWDS. The display function was implemented for demonstration purposes, to simulate an AWDS response after invoking a function. The isopleth function was implemented to measure response times as part of another study. The parameter plot function was implemented to produce a resolution-intensive display for analysis in the graphic display presentation study area. The zoom and graphic interaction functions were, as mentioned previously, implemented because they could not otherwise be studied from a MMI point of view.

Figures 3-5 are photographs of the graphic display screen that illustrate the execution of these functions within the context of the menu-driven structure. Figure 3 shows the output (weather fronts and isobars) of the display function in a 1024 x 1024 viewport. The background map consists of approximately 7000 vectors. The menu viewport shows hierarchy module 1.1.5 (data indicator), meaning that the operator is in the process of carrying out the isopleth function. The "formatted binary" menu entry is color-coded (not apparent in the black-and-white photograph), indicating that this type of data is available in the data base.

Figure 4 shows the output from the isopleth (isobars are shown) and plot functions. It illustrates a display option that was implemented to allow us to emulate, through pixel replication, a 512 x 512 full-screen display. The plot model is an early attempt at creating the surface standard parameter plot, without visibility and barometric tendency and characteristic (see Section 7.1.2). The menu viewport shows an early version of the horizontal analysis composite product command menu (hierarchy module 1.1 in Appendix C).

Figure 5 show how two 512 x 512 viewports can be used to emulate two physical 512 x 512 AWDS monitors. The right viewport shows weather fronts produced by the display function. The left viewport shows isobars produced by the isopleth function. The menu viewport illustrates the "add character" graphic interaction function. The user has selected in order, as they appear dynamically, the letter "L", the color, character size, and line width; and is in the process of placing the character in the left viewport.

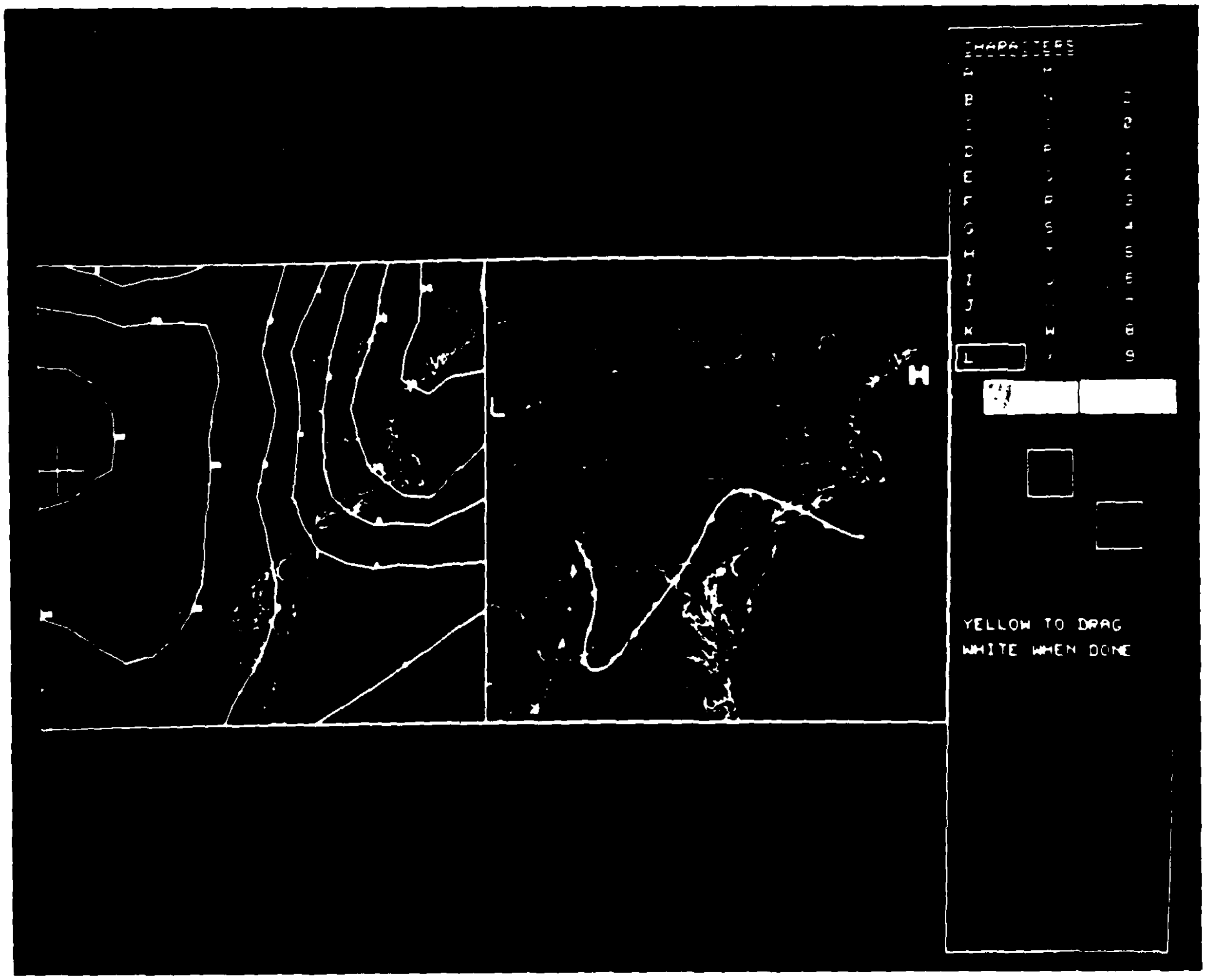


Figure 3. Implementation of Applications Functions, Photograph #1

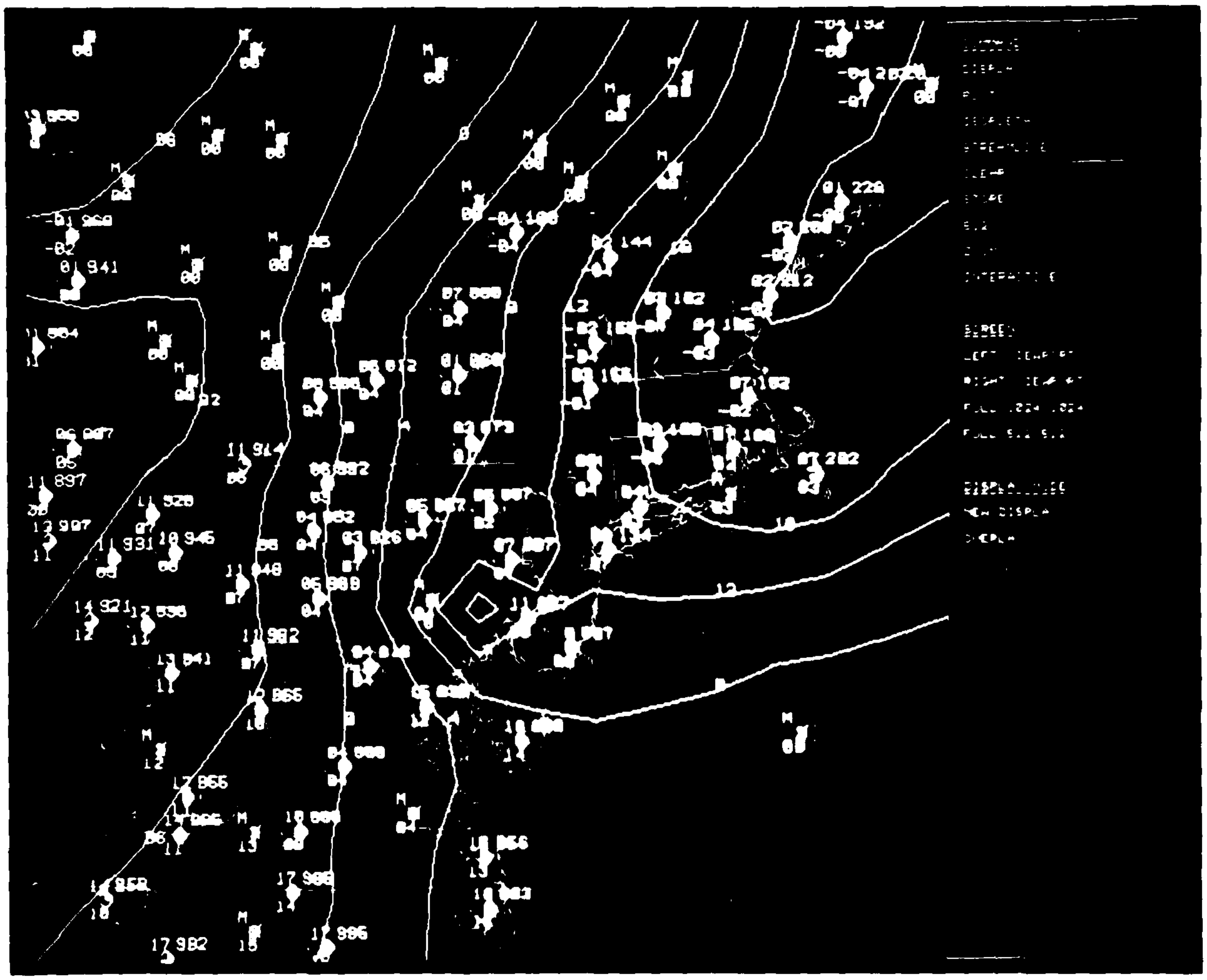


Figure 4. Implementation of Applications Functions, Photograph #2

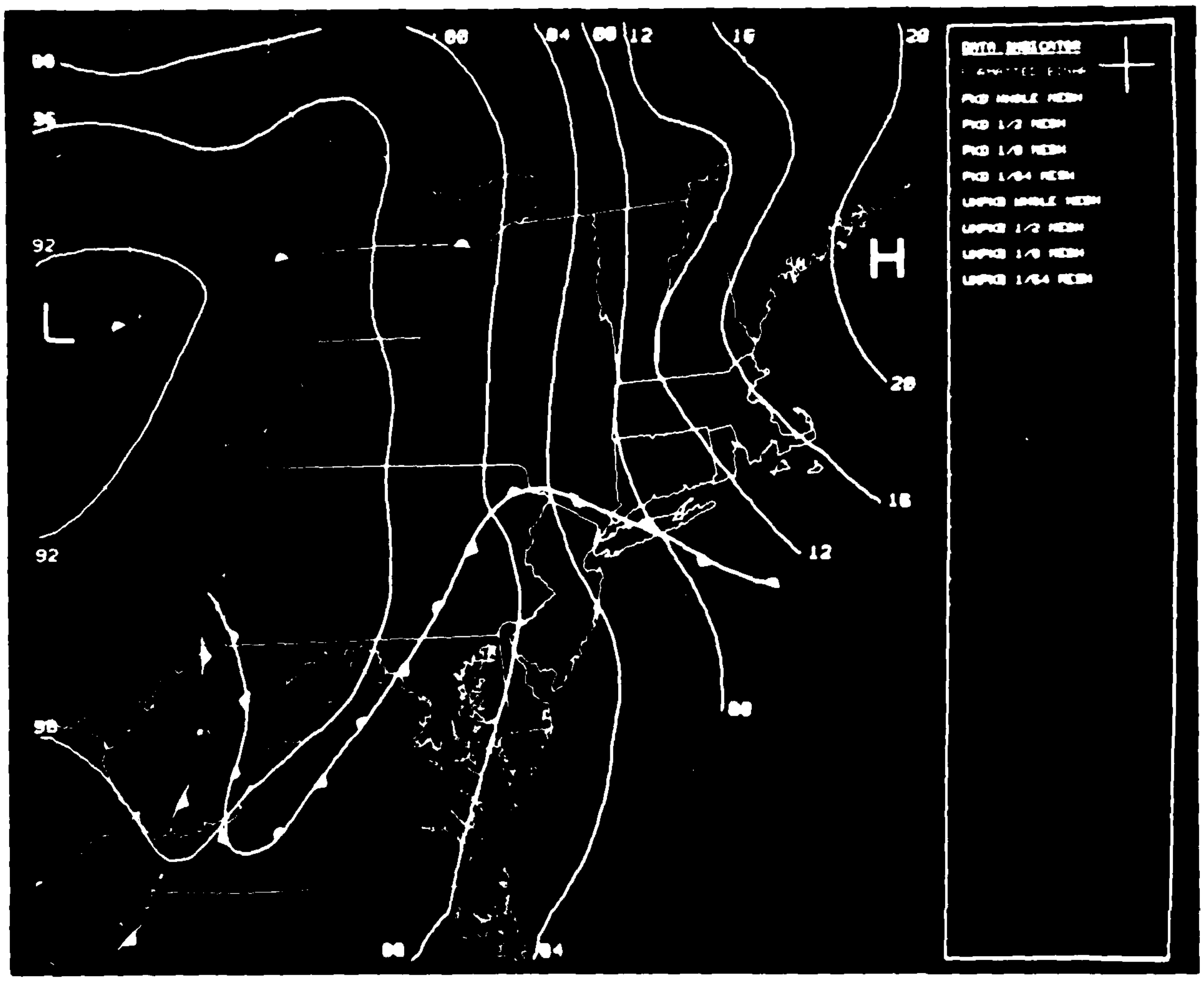


Figure 5. Implementation of Applications Functions, Photograph #3

7.0 GRAPHIC DISPLAY PRESENTATION STUDY

The graphic display presentation study area encompassed two tasks:

(1) The study of graphic depictions of various weather symbology; and

(2) The study of data density and product complexity levels for various graphic products.

7.1 Display of Weather Symbology

This study area focused on the definition of candidate depictions for weather symbols, parameter plot models, and symbolic lines on AWDS graphic displays. Due to the resolution requirements for AWDS graphic monitors, a balance between clarity and display space must be achieved to maximize informational content.

Three routines were developed on the AGDS to facilitate the creation and display of symbols, parameter plot models, and symbolic lines.

7.1.1 Symbols Routine

The symbols routine provides the capability to create and display up to five pixel pattern depictions (instances) for each of the symbols listed in Table 30.4.12 of the System Specification. The symbols are stored in an indexed file structure and are displayed in their actual pixel pattern representation as well as a pixel-replicated representation that simulates their appearance on a 512 x 512 monitor. Font size is also shown. The symbols program provides four options:

(1) Display all instances of a symbol;

(2) Add a pixel pattern instance by filling squares in a 20 x 20 grid template;

(3) Modify a pixel pattern instance by filling and deleting squares on the grid template; and

(4) Delete an unwanted instance of a symbol.

Several candidate instances of each symbol were implemented to illustrate tradeoffs between legibility and economy of representation. Font sizes that provide the best balance are:

(1) Present Weather - 11 x 11 font size, except for blowing dust (7 x 17), heavy snow (17 x 16), shower with mixed rain and snow (7 x 16), thundershower with mixed rain and snow (16 x 18), and past weather - blowing dust (14 x 17);

(2) Cloud Type - 11 x 11 font size;

(3) Cloud Amount Total - 9 x 9 font size; and

(4) Barometric Characteristic - 7 x 5 font size.

These font sizes do not include a blank border surrounding the lighted pixels.

Figures 6 and 7 illustrate the use of the symbols program. Both figures show the display of all available instances of six meteorological symbols: 1) shower during the past hour (WPH); 2) cumulonimbus with anvil (CB9); 3) ground fog (GF); 4) severe turbulence (TBS); 5) tropical storm - southern hemisphere (TSS); and, 6) snow grains (SG). Each symbol instance is displayed (in its default color) in both its actual and its pixel-replicated (equivalent 512 x 512) representation. Figure 6 shows the menu used to select the symbol, the symbol instance (if appropriate), and the operation to be performed. Figure 7 illustrates the addition or modification of a symbol instance (in this case, an instance of WPH) using the grid template. Upon completion, the user can decide to keep or discard the newly added or modified symbol instance.

7.1.2 Parameter Plot Model Routine

The parameter plot model routine displays surface parameter plots for al. (or a subset of) the reporting stations within a map area. The standard surface plot, depicted in Figure 8, includes the parameters and display formats described in Table 7. A strict interpretation of the requirements for the surface plot, as depicted in Figure 9, requires a rectangular display area of 67 x 36 pixels. Figure 9 uses a character size of 6 x 8 pixels, a popular size. On the 512 x 512 viewport, these characters are large enough to meet the Specification requirement that characters on a graphic monitor shall subtend a minimum of 20 minutes of vertical arc at a viewing distance of 20 inches. On the 1024 x 1024 viewport, however, a

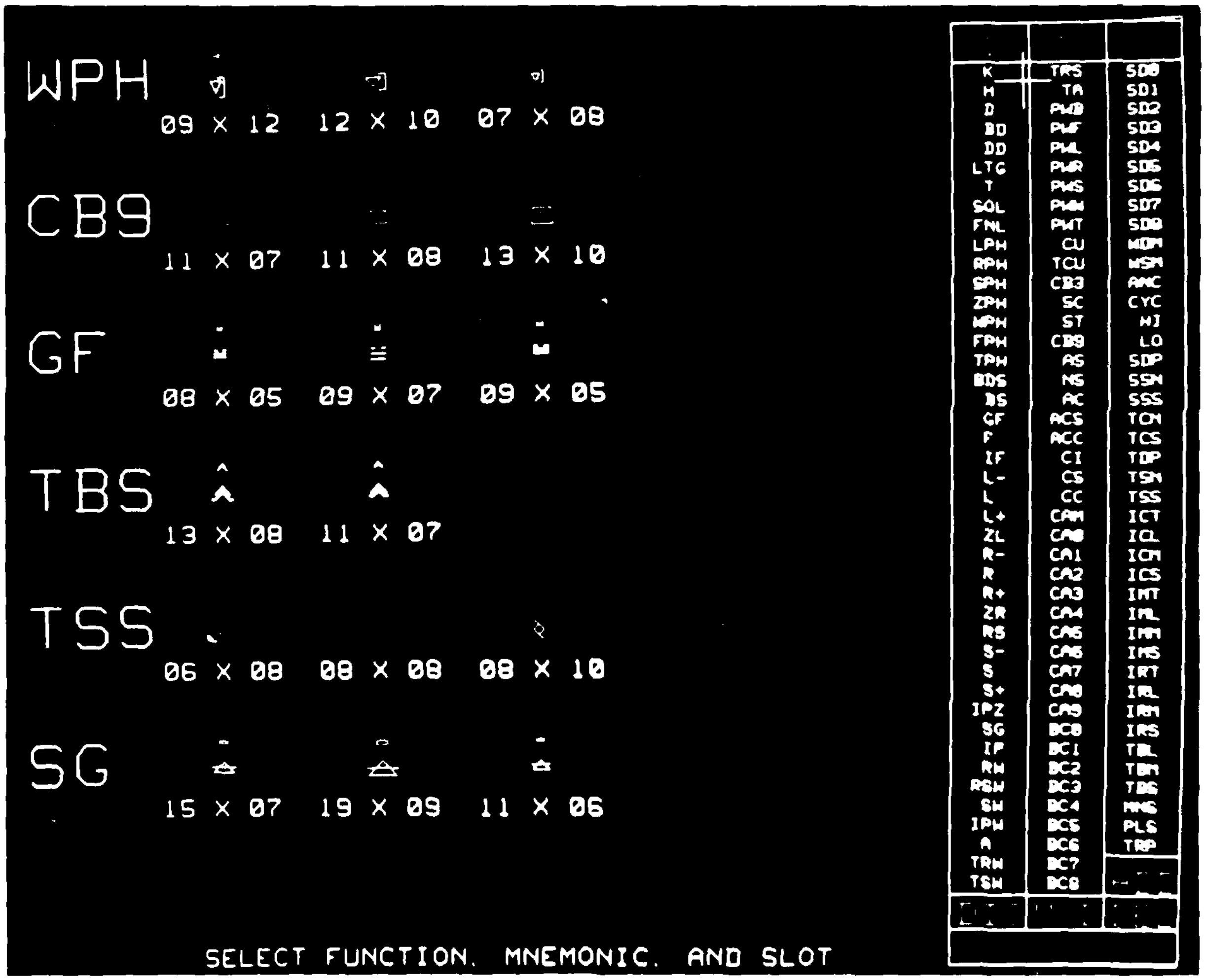

WPH
09 X 12
12 X 10
07 X 08
CB9
11 X 07
11 X 08
13 X 10
GF
08 X 05
09 X 07
09 X 05
TBS
13 X 08
11 X 07
TSS
06 X 08
08 X 08
08 X 10
SG
15 X 07
19 X 09
11 X 06
K H D BD DD LTG T SOL FNL LPH RPH SPH ZPH FPH TPH BDS GF F IF L- L L+ ZL R- R R+ ZR RS S- S S+ IPZ SG IP RH RSH SH IPH A TRH TSH
TRS TA CU TCU CB3 SC ST CB9 AS NS AC ACS ACC CI CS CC CA1 CA2 CA3 CA4 CA7 BC1 BC2 BC3 BC4 BC5 BC6 BC7 BC8
SD1 SD4 SD7 CYC HI LO SSS TCS ICT IRT PLS
SELECT FUNCTION, MNEMONIC, AND SLOT

Figure 6. The [illegible]

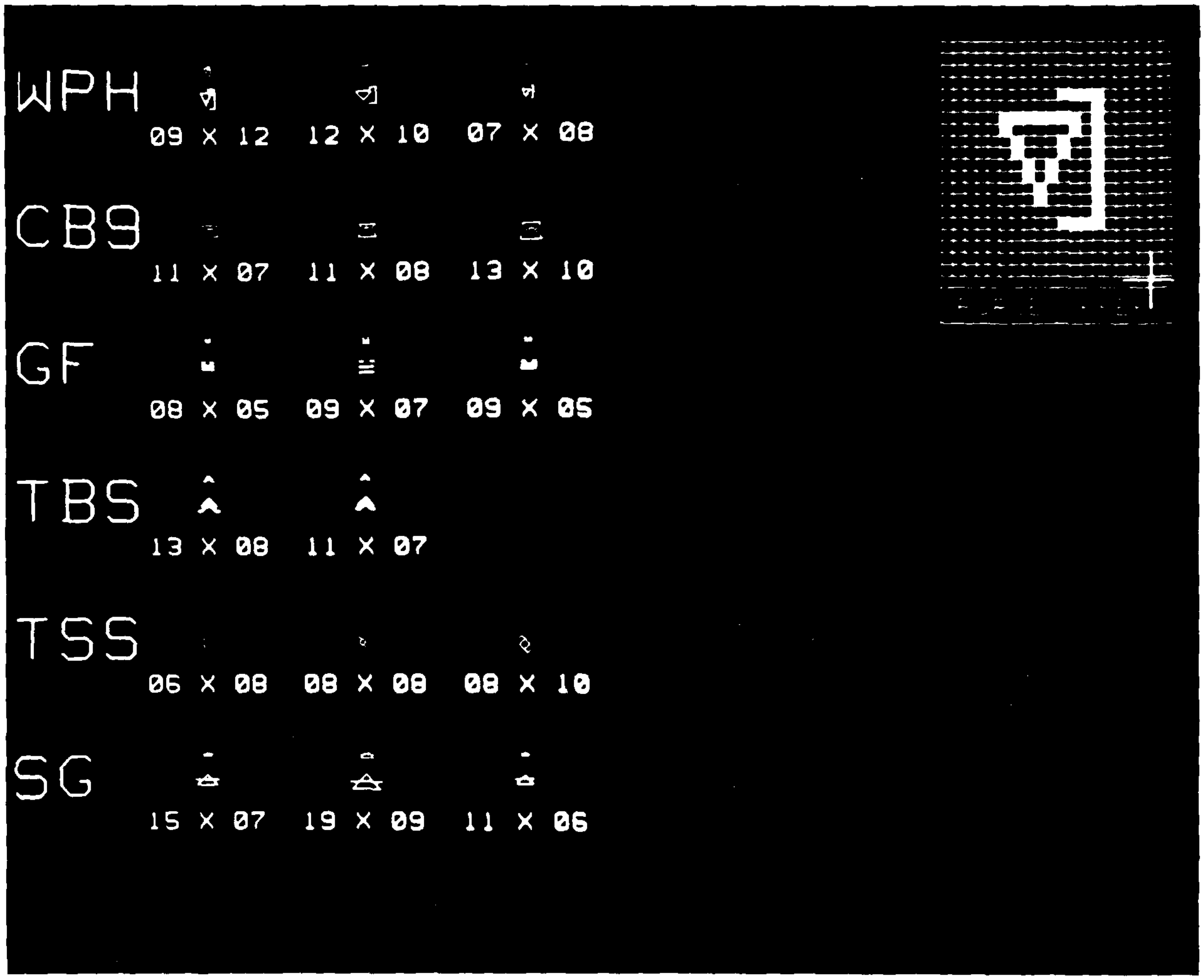


Figure 7. The Symbols Program, Photograph #2

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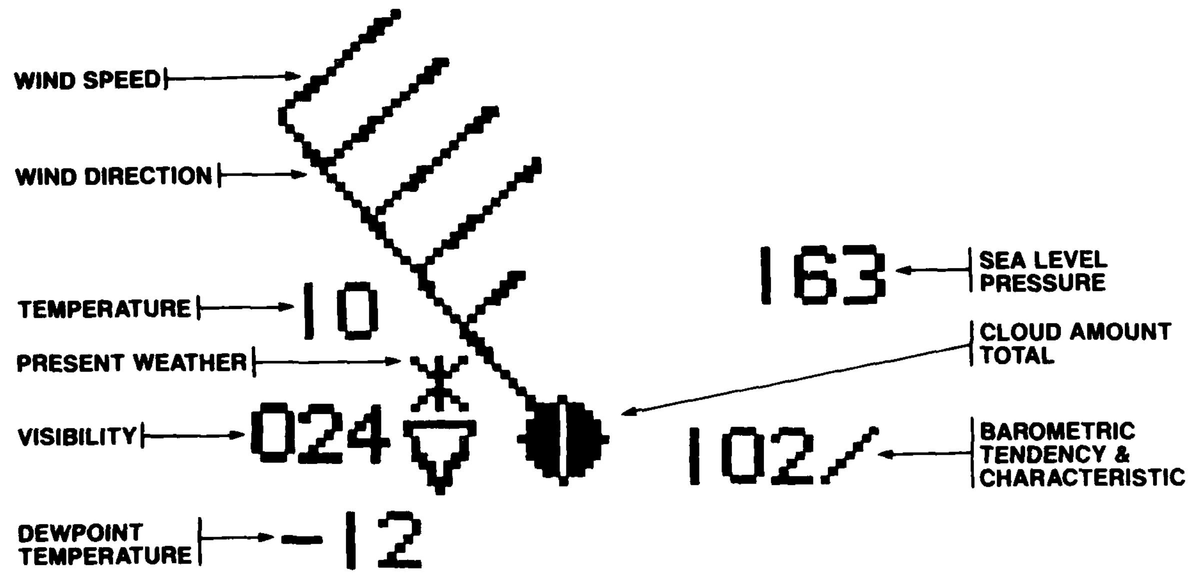

Figure 8. A Typical Standard Surface Parameter Plot

Table 7

Parameters and Formats for the Standard
Surface Parameter Plot

Cloud Amount Total

The symbol for cloud amount total is centered at the geographic location of the reporting station.

Wind Direction

A solid line (wind shaft) is drawn extending outward from the cloud amount total symbol toward the direction from which the wind is blowing. If the wind speed is calm, rather than drawing the shaft, a circle is drawn concentrically around the cloud amount total symbol.

Wind Speed

Solid lines (wind barbs) and/or solid triangles (wind pennants) are drawn perpendicularly from the wind shaft. A short barb represents five knots, a long barb represents 10 knots, and a pennant represents 50 knots.

Present Weather

The present weather symbol is displayed to the left of the cloud amount total symbol.

Temperature

A three-digit numerical value (e.g., -12) for temperature in degrees Celsius is displayed above the present weather symbol.

Dewpoint Temperature

A three-digit numerical value for dewpoint temperature in degrees Celsius is displayed below the present weather symbol.

Visibility

A three-digit numerical value (e.g., 124 for 12-4/8 miles) is displayed to the left of the present weather symbol.

Table 7 (continued)

Pressure

A three-digit numerical value (e.g., 528 for 952.8 or 1052.8 millibars - the hundreds-digit and thousands-digit are dropped) is displayed to the upper right of the cloud amount total symbol.

Barometric Tendency and Characteristic

A three-digit numerical value (e.g., 125 for a change of .125 inches of mercury) and the symbol for characteristic (which indicates the sign of the change) are displayed to the lower right of the cloud amount total symbol.

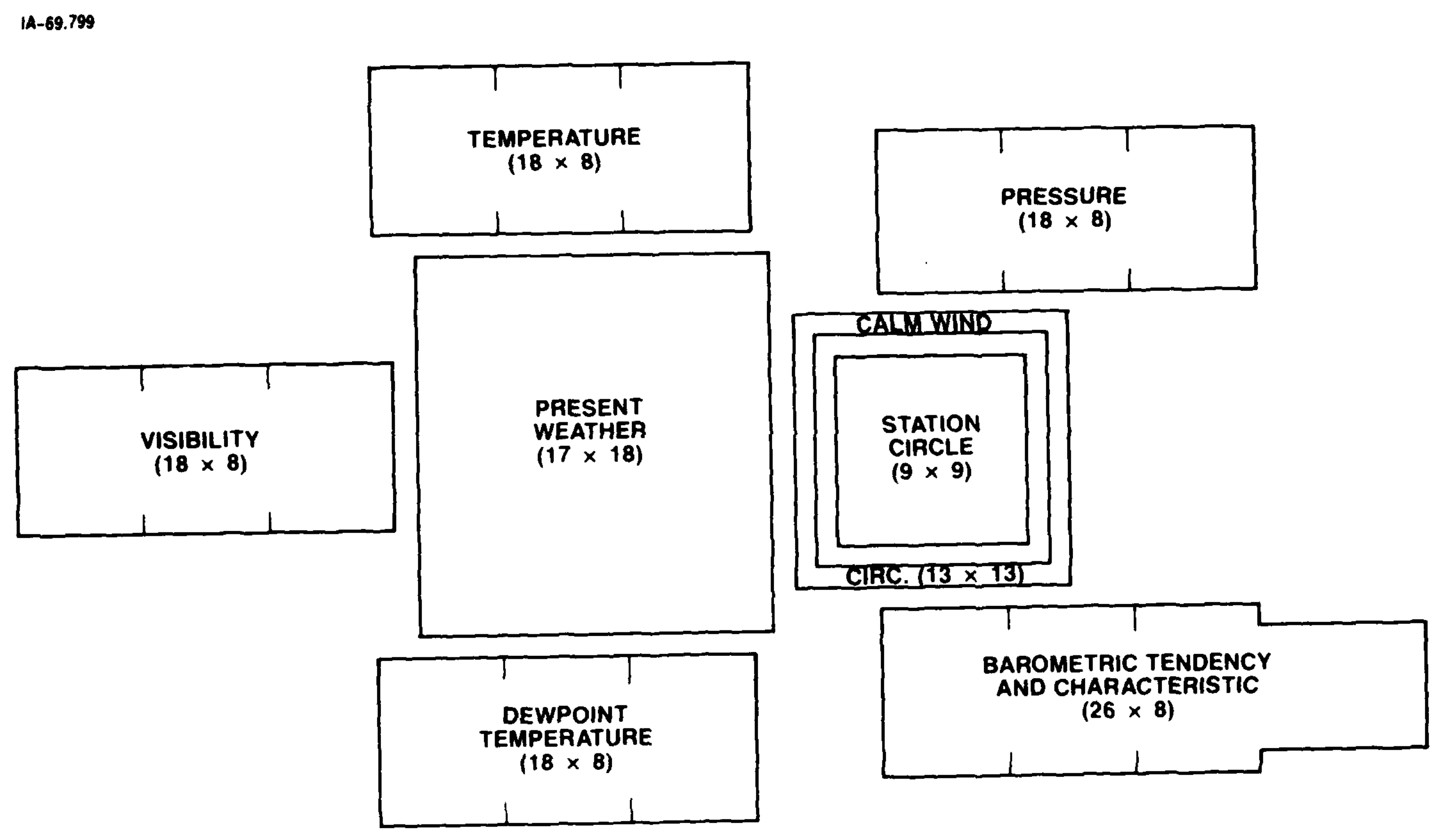

Figure 9. Layout of the 67 x 36 Standard Surface Parameter Plot Model

9 x 12 font is needed to meet the same requirement. The Specification is more relaxed for character size on an alphanumeric monitor - characters need to subtend only 15 minutes of arc. If higher resolution graphic monitors were adopted for AWDS, the more relaxed character size would be adequate for characters in plot models - readability of these characters is not more critical than readability of text.

The plot program alternately allows the user to reduce the overall plot model size by the selection of one or more display options:

(1) Eliminate the space for calm wind circle and, as an alternative, highlight (color code) the cloud amount total symbol when winds are calm;

(2) Move the visibility to the right of the cloud amount total symbol (thereby making the parameter plot more symmetric, and reducing rectangular area);

(3) Use alternate representations of the five outsized present weather symbols so that the font size needed to accommodate all present weather symbols can be reduced from 17 x 18 to 11 x 11;

(4) Eliminate the minus sign for negative temperature and dewpoint temperature values, and, as an alternative, highlight (color code) negative values; and

(5) Exploit the variable vertical extent of (or the possible absence of) the present weather symbol by allowing the temperature and dewpoint temperature fields to be dynamically repositioned downwards and upwards, respectively.

Selection of Options 1, 2, 3, and 4, collectively, reduces the rectangular size of the parameter plot model to 44 x 29 pixels (see Figure 10), again based on a 6 x 8 character font size. Concurrent selection of Option 5 will further shrink the upper left and lower left corners of the plot model.

Display of the wind flag (wind speed and direction) also needs to be considered. Because the wind shaft orientation is a function of wind direction, the wind flag often tends to impinge on other displayed parameter plot variables, degrading overall readability. One way to minimize this problem could be to eliminate wind barbs and represent wind speed by color-coding the wind shaft. If

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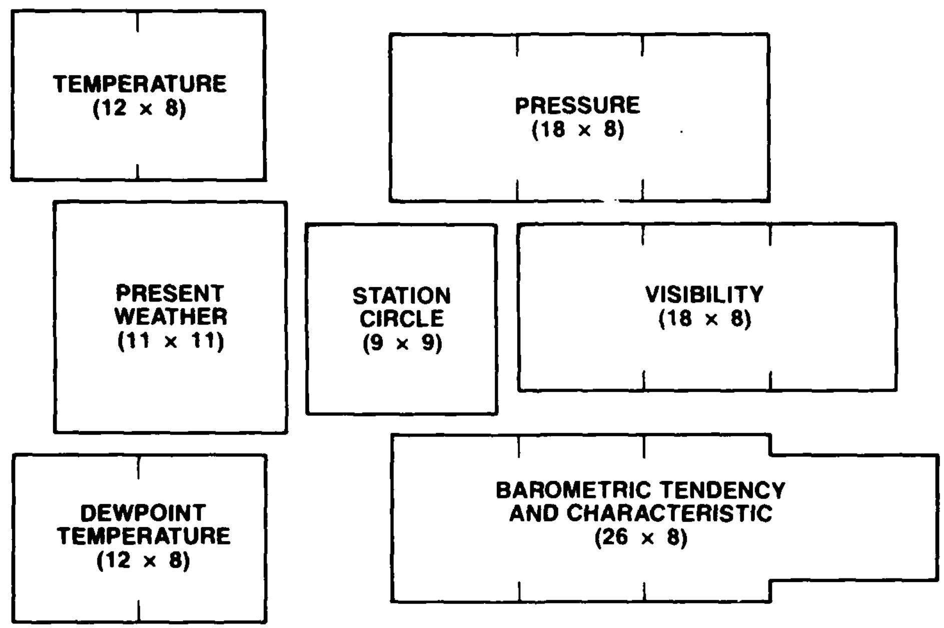


Figure 10. Layout of the 44 x 29 Standard Surface Parameter Plot Model

the shaft was divided into three piecewise line segments, individual color codings could be used to denote the number of five-knot wind speed increments (0 or 1), ten-knot increments (0 to 4), and 50-knot increments (0, 1, or more), that sum to give the actual wind speed.

Section 7.2 describes how selection of the various options for reducing parameter plot model size can increase the total number of plots displayable on the graphic monitor.

7.1.3 Symbolic Lines Routine

The symbolic lines routine supports the creation and display of symbolic lines such as weather fronts and outlines of cloud or precipitation areas. For each symbolic line, the program permits selection of composition parameters that determine the appearance of the line. For weather fronts (cold, warm, stationary, and occluded fronts), these parameters include line width, pip size, and pip spacing. Tests suggest that weather fronts should be composed as follows:

(1) Weather frontal lines should be at least twice as wide as isopleth lines;

(2) Pips should be one to two times as large as the alphanumeric characters in parameters plots; and

(3) Pip spacing should be five to ten times the pip width.

7.2 Product Complexity Levels

This study focused on determining how much information should be included in externally-generated products (e.g., large-scale weather charts) and locally-generated products (e.g., regional-scale weather charts). Product complexity levels depend on:

(1) Size and number of station parameter plots (locally-generated products only);

(2) Number of isopleths and symbolic lines; and

(3) Resolution of the map background.

For station parameter plots, the goal was to determine how many plots could be clearly displayed on a map of the Northeastern United States (825 square nautical miles). There are far too many surface stations in the area for display on a 512 x 512 graphic monitor, even with a simple parameter plot model. Recognizing this problem, the Specification allows for a display prioritization scheme, whereby the number of displayed stations per unit geographical area increases as a function of the Zoom B zoom ratio (1x, 2x, 4x, 8x, and 16x magnification). Table 8 shows how many station plots can be displayed, without physical overlap of parameters between adjacent plots, for each zoom ratio, and for various viewport resolution and plot model combinations. The test data set contained weather observations for 172 surface stations in the region. The "standard" plot is as depicted in Figure 9, and the "condensed" plot is as depicted in Figure 10. As described in Section 7.1.2, "normal" characters are 6 x 8 pixels, and "large" characters are 9 x 12 pixels. Tests show that the normal character size could be used on the 1024 x 1024 viewport with little loss in readability compared to the large character size - and with a significant gain in the number of displayable parameter plots.

Increasing the zoom ratio dramatically increases the number of displayable parameter plots, especially at lower zoom ratios. Use of the higher resolution viewport is equivalent to doubling the zoom ratio, without decreasing overall display area. As a result, the 16:1 zoom ratio, which in any case produces a map scale too small for relevance to synoptic scale analysis, is hardly necessary for the 1024 x 1024 viewport.

The use of the condensed plot in place of the standard plot did not make a large difference in the number of parameter plots displayable without overlap - but the numbers in Table 8 are misleading. We found that, owing to the asymmetry and sparse configuration of the standard plot, its use led to a cluttered display, and it became difficult to associate displayed parameters with the correct surface station, even when no physical overlap occurred. For the standard plot in the 512 x 512 viewport, the practical upper limit was 36 rather than 48 plots for the 1:1 zoom ratio. The additional 20 station plots that can be added using the condensed plot would be very helpful in tasks, such as weather frontal analysis, where the forecaster needs to derive a mental picture of the weather over a geographical area.

While parameter plots are a critical resolution driver, isopleths and symbolic lines are not. The 512 x 512 viewport seems to provide adequate resolution for display of several parameter fields, although clutter makes it difficult to assimilate more than three at the same time, even for the higher resolution viewport.

Table 8

Number of Parameter Plots Displayable as a Function of Viewport Resolution, Plot Model, and Zoom Ratio

Viewport Resolution and Plot Model Type	Zoom Ratio 1:1	2:1	4:1	8:1	16:1
512 x 512 Viewport; Standard Plot	48	92	135	156	170
512 x 512 Viewport; Condensed Plot	56	102	140	165	170
1024 x 1024 Viewport; Standard Plot; Large Characters	77	109	141	168	172
1024 x 1024 Viewport; Condensed Plot; Large Characters	87	133	156	170	172
1024 x 1024 Viewport; Standard Plot; Normal Characters	92	135	156	170	172
1024 x 1024 Viewport; Condensed Plot; Normal Characters	102	140	165	170	172

The map background must have adequate resolution to enable the operator to distinguish small-scale geographic features at a 16x zoom ratio. The Specification allows for 27,000 vectors per map background. The AGDS clearly shows, however, that for a Northeastern United States map background containing only 7000 vectors, familiar small-scale geographic features, such as Cape Cod, are unmistakable at a 16x zoom ratio.

8.0 CONCLUSIONS AND RECOMMENDATIONS

A prototyping tool, such as the AWDS Graphic Development Systems (AGDS), can aid requirements definition for man-machine interfaces to on-line systems. For AWDS, the AGDS studies were effective in formulating a number of key recommendations for the design of MMI and graphic display presentation functions. These are summarized in Section 8.1.

As a corollary to this effort, recommendations for the general application of system simulation studies in system acquisition programs are discussed in Section 8.2.

8.1 Specific Conclusions of the Study

Three categories of conclusions and recommendations for specific application to AWDS have emerged from the AGDS studies: 1) those relating to the MMI; 2) those relating to the Interface Control Drawing (ICD) product identifier structure which strongly influences the MMI; and 3) those relating to graphic display presentation.

8.1.1 Man-Machine Interface

If a single interface structure is selected for AWDS, the menu-driven interface appears to be more desirable than either the command line syntax or the prompted entry structure. Some key reasons are:

(1) The menu-driven interface is the best at guiding the user through the input process, a primary design factor considering the aggregate complexity of AWDS and the probable overall inexperience of the novice AWDS user;

(2) The menu-driven interface would be reasonably quick to use if the product identifier structure were simplified (see Section 8.1.2);

(3) The menu-driven interface frees up the alphanumeric terminal for dedicated support of the many alphanumeric processing functions that are part of AWDS; and

(4) The basic menu-driven framework does not appear to be more complex to implement than the other two interface structures.

These reasons reflect the rationale that, if a tradeoff must be made, the need for comprehensive user support is more critical than the need for speed of use. As discussed in Section 4.2, the novice user will probably be learning how to do his job at the same time he is learning how to use the system. Further, the system may be so complex that even the operator who is both an experienced weather technician and AWDS user would be better served by a system-initiated dialogue when performing certain sets of commands.

The best MMI solution, however, would be to combine the menu-driven and command line syntax structures into a single interface structure. If properly designed, this combination would facilitate ease of use by employing a self-teaching feature to accelerate the transition from use of the menu-driven structure to use of the command line syntax. To accomplish this, the two input styles should be completely interchangeable on a parameter-by-parameter basis. Selection of a menu item should produce an echo of the equivalent command line syntax representation in a viewport adjacent to the menu viewport on the graphic screen, allowing the user to visualize how a command line is built. As the user becomes more familiar with the system, he could graduate to use of the command line entry in a self-paced fashion.

8.1.2 Product Identifier Structure

The speed of command entry directly depends on the number of input steps involved, and, for menu-driven structure, the number of entries in each menu (since it takes a finite amount of time to display each entry). To accelerate input speed, the baseline assumption (see Section 6.1.2) of equivalence between product identifier fields and retrieval keys needs to be challenged. The product identifier allows for a considerable amount of redundancy, irrelevant parameters, and invalid parameter combinations - variability that should not be manifested in the retrieval function. The solution to this problem could be achieved without altering the basic structure of the product identifier, only its application. It should first be agreed which product identifier fields are unnecessary for unique product identification and retrieval - these could be blank-filled when transmitted and/or ignored by AWDS for later product retrieval. Then a set of rules could be established that describe which possible values of the remaining product identifier fields are valid on a product type basis. These lists could be extended later if the contractor ensures that his MMI design is flexible.

Some specific suggestions for simplifying product identification and retrieval are:

(1) Eliminate the need for the File Indicator (F) as a retrieval key (this is already reflected in the hierarchy presented in Appendix C);

(2) Eliminate the need for the Data Type Subcategory (TT) as a retrieval key;

(3) Eliminate the need to specify UGDF mesh size and UGDF and Pixel Product packing format as part of the Data Type Indicator (D);

(4) Eliminate multiple part numbers from the Base Time/Part Number field;

(5) Eliminate the possibility for combining into a single product two or more parameters listed for the Parameter and UGDF Mnemonic field; and

(6) Eliminate the PI Set Code and replace it with the Geographic Designator (AA), eliminating the confusion and associated slowness of input caused by the use of two separate geographical indicators.

Adoption of these suggestions would reduce the hierarchies described in Appendix C to a set of inputs familiar to any weather forecaster - e.g., function, parameter, time, geographical area, and atmospheric level. These changes could also accelerate menu-driven input to the point where it would not be significantly slower than command line input.

8.1.3 Graphic Display Presentation

Several recommendations emerged from the graphic display presentation study area. These are:

(1) Limit the font sizes to 11 x 11 for present weather, 11 x 11 for cloud type, and 9 x 9 for cloud amount total;

(2) Adopt modified 11 x 11 pixel pattern representations for the five outsized present weather symbols;

(3) Adopt the suggestions for shrinking the surface standard plot model to 44 x 29 pixels; and

(4) Limit map backgrounds to, at most, 10,000 vectors.

The study also showed that a higher resolution monitor would facilitate interactive weather analysis because a larger number of parameter plots could be displayed simultaneously.

8.2 General Recommendations for Use of Prototyping Studies

As a contract monitor in an acquisition program, visibility into the MMI design process is necessary to enhance the overall success of a system. The MMI should be studied from the start of the acquisition process in order to fold high-level requirements for MMI design into the System Specification. System simulation studies can also be influential in a contract monitoring relationship to ensure that the MMI design progresses in the right direction. This requires that the contract monitor demonstrate credibility and insight into the particular MMI design problem, qualities best obtained through system simulation studies.

The following sections provide suggestions for using system simulation studies for approaching MMI development as a requirements definition activity and as a contract monitoring tool.

8.2.1 Man-Machine Interface Requirements Definition

The first logical step in MMI design is to perform a user requirements study and task analysis to develop an understanding of the problem area and the prospective user, and to study how the user performs his job in the current environment. The task analysis should provide a set of functional requirements to be made available through the MMI. Once these functional requirements are understood, the MMI design can be formulated. A top-down design approach will define, in order, the conceptual design (the high-level MMI model), the semantic design (operations performed and their effects), the syntactic design (user's logical actions and their effects), and the lexical design (binding of language tokens to physical actions). Requirements definition for the higher levels in the top-down design approach is consistent with the goals of a System Specification. With the higher level model in hand, the tools provided by Smith [SMIT83a] can then be applied to generate a tailored set of system specifications.

In summary, system simulation studies can be used to:

(1) Develop candidate MMI models and test them on the prospective user;

(2) Identify problems with the application of a given model that might otherwise be overlooked;

(3) Use the results of (1) and (2) as an input to Smith's methodology for defining MMI requirements for the System Specification; and

(4) Thereby, reduce risks associated with leaving the entire MMI development job to the contractor. These risks include:

   a) Insufficient budgeting for design and implementation of the MMI, and

   b) Cost growth on contract if the Government finds the resulting MMI to be unsuitable.

8.2.2 Monitoring Man-Machine Interface Development

High-level MMI design guidelines, based on system simulation studies, can alternatively be provided to the contractor as non-binding information at early requirements reviews, such as System Requirements Review (SRR) or System Design Review (SDR). This is recommended on the AWDS program. If the proposed MMI model does not conflict with other design plans (such as those that reflect use of existing contractor software), then the contract monitor has a good chance of influencing the MMI in a positive direction.

Prototyping studies can also be a useful evaluation tool through Critical Design Review (CDR). If the simulation system is composed of a core of functions relevant to the conceptual model described by the System Specification and/or adopted by the contractor, then it can be easily applied to test key elements (and users' reactions to those elements) of the contractor's design.

LIST OF REFERENCES

FOLE82 Foley, James D. and Andries Van Dam, Fundamentals of Interactive Computer Graphics. Reading, MA: Addison-Wesley, 1982.

SMIT83a Smith, Sidney, L., User-System Interface Design in System Acquisition. ESD-TR-84-158, Electronic Systems Division, AFSC, Hanscom AFB, MA, April 1984. AD A140956.

OCR-AWDS-01 System Specification for the Automated Weather Distribution System (AWDS). July 1983.

APPENDIX A

THE AGDS STUDY PLAN

STUDY AREA #1 - GRAPHIC DISPLAY PRESENTATION

The incentive for the graphic display presentation study area comes from the fact that AWDS graphic display monitors will not be able to provide the high resolution traditionally expected from facsimile machines and hand analyses. The plot function has been identified as a particularly severe resolution driver. It is, therefore, critical to devise methods promoting highly efficient use of display resources. Optimum use of display resources will be achieved through economic representation of weather symbols and features, intelligent use of color, careful partitioning of display screens into viewports, and use of tools such as the zoom B function. Clarity in the presentation of data cannot be sacrificed.

Sample tasks in the graphic display presentation study area are:

1.1 Selection of an optimum font size for meteorological symbols (present weather and cloud type):

Set up and display pixel pattern representations of weather symbols (Table 30.4.12 of the AWDS Specification) using several different candidate font sizes (e.g., 6 x 8, 10 x 14, 15 x 20).

1.2 Depiction of the standard plot model:

1.2.a. Given the optimum symbol font sizes selected above, implement the plot function and determine an optimum standard plot model size.

1.2.b. Examine how intelligent use of color could be used to improve plot model clarity and to reduce optimum plot model size. For example, if the wind barb tends to obscure underlying plot data, investigate whether use of color (or reverse video) can correct this.

1.3 Display requirements for LAWC plot fields:

1.3.a. Display the background map and the two vector graphic products and determine how many station parameter plots can be displayed at the 1:1 zoom ratio.

1.3.b. Use the windowing algorithm in the Lexidata software to simulate the zoom function, and determine how many station parameter plots can be displayed at various higher zoom ratios.

1.4 Depiction of symbolic lines:

Determine optimum feature sizes for symbolic lines (Table 30.4.14 of the AWDS Specification). This may require viewing symbolic lines at different orientation angles on the display screen.

1.5 Display requirements for composite products:

Digitize several of the products in Section 6.6 of the AWDS Specification in order to determine how clearly they can be displayed on a 512 x 512 simulated pixel resolution display screen.

1.6 Study of partitioning of display screen real estate:

Given a LAWC display, examine how viewports could be included for product title, menus, error messages, and prompts without seriously degrading the readability of the product or the amount of product data displayed.

STUDY AREA #2 - GRAPHIC USER-SYSTEM INTERFACE

The graphic user-system interface study area will be used to determine the most effective methods for user interaction with the AWDS system. Graphic processing - especially interactive graphic processing - is highly flexible, and there is an almost endless variety of methods for structuring man-computer dialogues - from simple command syntaxes to sophisticated menus, and from minimal user hand-holding to liberal use of prompting, default parameter values, explanatory messages, and error recovery. It is particularly important to keep the user in mind when designing the graphic interface. Inexperienced users prefer friendly user-forgiving interfaces, while experienced users are more interested in dialogue structures designed for speed of interaction.

Study of the user-system interface also includes determining how to map logical input functions to physical input devices. For AWDS, interaction with a function or family of functions could be mapped 1) to the keyboard only; 2) to the graphic tablet only; or 3) to the keyboard/tablet combination. Different data input requirements will make the keyboard/tablet combination the most natural mapping for some AWDS functions; however, this should be avoided where possible because ergonomic considerations favor the use of a single input device for control of a given function.

There are a number of AWDS functions that make good candidate topics for the user-system interface study area; however, highest priority should be given to 1) the composite product function; and 2) the graphic interaction function. These key functions will have heavy routine use in the AWDS system, and they are functions that embody important complementary aspects of graphic user-system interfaces.

Sample tasks in the graphic user-system interface study area are:

2.1 Composite product function interface:

The following are various methods for initiating functions in the horizontal analysis product and cross section product composite function families. This is not a comprehensive list, but it is intended to provide a variety of candidate input methods from the simple (to implement) to the sophisticated. Each interface method should be tested for one or more of the functions in one of the composite product families. It is not necessary to implement the actual functions that the commands are supposed to invoke; for the purposes of this user-system interface study, some minimal system feedback to operator inputs is probably sufficient.

2.1.a. Direct command/argument entry from the alphanumeric terminal:

This input method involves a direct executive-type command line entry with no system prompting. This method is the simplest to implement, but is the most difficult to use because the operator must fully understand the command syntax, order of argument entry, and valid argument values.

2.1.b. Prompted entry (without defaults) from the alphanumeric terminal:

Upon input of a command, the system prompts the user for entry of each command argument. A value for every argument must be entered because no default value support is included.

2.1.c. Prompted entry (with defaults) from the alphanumeric terminal:

This method is the same as 2.1.b., except that default values for each argument are displayed with each command argument prompt, and a simple return keystroke will cause selection of the default value. The origination of default values should also be investigated. There are a number of options. Default values could be: 1) pre-set at the time of system initialization; 2) set to the argument value used by the last invocation of the specific command; or 3) set to the last invocation of any of the commands in the particular composite product function family.

2.1.d. Entry using graphic display screen menus:

In their purest form, menus would allow for full interaction with composite product function commands and arguments using the graphic tablet/terminal combination. Arguments and argument values should be displayed on the graphic monitor and selected by positioning the tablet stylus "over" the desired input and pushing a button. Key study topics for AWDS are: 1) to examine how the menus can be designed for maximum user support and speed of input; and 2) to determine whether composite functions can be controlled by menus and the tablet/stylus combination, or whether keyboard input is an additional necessity.

2.2 The graphic interaction function:

The graphic interaction function is a family of six functions: Add, Delete, Modify, Relocate, Highlight, and Polygon-Fill. The actual commands for initiation of these functions could be mapped to either the keyboard or the graphic tablet. Interaction with each function is ideally suited to use of the tablet, although selection of colors, symbols, and symbolic lines could be mapped to either the keyboard or the tablet. For most functions, there are a variety of design possibilities that should be explored. A few of these are given below for each function.

2.2.a. Add (symbol):

- o Select color; draw symbol in freehand style.
- o Select color; select symbol using keyboard or tablet; locate desired symbol position; system will redraw symbol at new location.
- o Select color; select symbol from menu; drag symbol to desired location.

2.2.b. Add (symbolic line):

- o Select color; draw symbolic line in freehand style.
- o Select color; select symbolic line using keyboard or tablet; draw a solid line in freehand style; system will replace the solid line with the desired symbolic line.

2.2.c. Delete, highlight, or polygon-fill:

- o Pick feature of interest using graphic tablet; system will delete or highlight that feature, or polygon-fill that closed symbolic line.

2.2.d. Relocate (symbol):

- o Pick feature; locate new feature position; system will redraw feature at new location.

- o Pick feature; drag feature to new location.

2.2.e. Relocate (symbolic line):

- o Pick feature (and feature reference point); locate new coordinates of the reference point; system will redraw feature with the same orientation, with the old feature reference point coinciding with the new coordinates.

- o Pick feature (and feature reference point); drag feature to new location.

2.2.f. Modify symbolic line:

- o Delete feature; add feature.

- o Pick feature; retrace feature with desired modifications; system will delete the old copy of the feature upon the push of a button.

- o Pick feature (and first point on feature); pick second point on feature; redraw (add) selected portion of feature; system will delete old portion.

- o Pick feature (and first point on feature); redraw portion of feature until old copy of the feature is re-intersected; system will delete old portion.

APPENDIX B

CATEGORIZATION OF SYSTEM SPECIFICATION
MMI REQUIREMENTS

(G) 1. Perform the graphic interaction function (3.2.1.1.1.2.1, p. 32).

(G) 2. Set up loop or sequence (3.2.1.1.1.2.1.2, p. 37).

(G) 3. Run the loop or sequence (3.2.1.1.1.2.1.2.1, 3.2.1.1.1.2.1.2.2, p. 37).

(G) 4. Perform the zoom A/roam function (3.2.1.1.1.2.1.2, pp. 37-38).

(G) 5. Perform the zoom B function (3.2.1.1.1.2.1.3, pp. 37-38).

(C) 6. Manage table of reporting station display prioritization (3.2.1.1.1.2.1.4.1, p. 39).

(G) 7. Temporarily override station display prioritization (3.2.1.1.1.2.1.4.1, p. 39).

(G) 8. Select UGDF plot grid intersection spacing (3.2.1.1.1.2.1.4.2, p. 39).

(C) 9. Manage table of airfield assignments for Flight Control Facilities (FCFs) (3.2.1.1.2.2, p. 41).

(A) 10. Select product types for Air Traffic Control (ATC) and Flight Operations (FO) displays (3.2.1.1.2.2.1.3, p. 41; 3.2.1.1.2.2.2.3, p. 42).

(C) 11. Control audio-visual alarms at ATC and FO displays (3.2.1.1.2.2.1.4, p. 41; 3.2.1.1.2.2.2.4, p. 42).

(C) 12. Manage table of graphic feature color assignments (3.2.1.1.3.1, p. 43).

(C) 13. Enter map data from Removable Magnetic Storage Media (RMSM) (longitude-X and map background entered manually) (3.2.1.1.3.3.2, p. 44).

(A) 14. Print any alphanumeric product (3.2.1.1.4, p. 45; 3.2.1.3.1, p. 57).

(A) 15. Print an alphanumeric display (3.2.1.1.4, p. 45).

(A) 16. Hardcopy alphanumeric product created using screen format capabilities (3.2.1.1.4, p. 45).

(G) 17. Hardcopy one to five overlaid graphic products (3.2.1.1.4, p. 45; 3.2.1.3.2, p. 58).

(A/G) 18. Manage command sequence (3.2.1.1.5.1, p. 46).

(A/G) 19. Execute command sequence (3.2.1.1.5.1, p. 46).

(A) 20. Construct/modify forms/formats (3.2.1.1.6, p. 46).

(A) 21. Fill in a form (create a product) (3.2.1.1.6, p. 46; 3.2.1.8.1, 3.2.1.8.2, 3.2.1.8.3, p. 92). (Also includes Automatic Responses to Queries (ARQs) and Addressed Messages.) (Also includes specifying routing upon completion.)

(C) 22. Manage list of forms/formats (3.2.1.1.6, p. 46).

(C) 23. Silence audible alert (3.2.1.1.7, p. 47).

(C) 24. Acknowledge alert notifications (3.2.1.1.7, p. 47).

(C) 25. Manage table of products in the data base and their retention criteria (3.2.1.1.8.d, p. 48; 3.2.1.6.7, p. 90).

(A) 26. Generate a locally-produced surface observation (3.2.1.2.1.1, p. 49). (Including display in transmission format and distribute.)

(A) 27. Generate a locally-produced upper air observation (3.2.1.2.1.2, p. 50).

(A) 28. Generate a locally-produced radar report (3.2.1.2.1.3, p. 50).

(C) 29. Manage table of products for product selection (3.2.1.2.3.1, p. 51).

(C) 30. Manage METWATCH criteria (3.2.1.2.4, pp. 52-55).

(C) 31. Manage table of products for product alert (3.2.1.2.5, p. 56).

(A) 32. Display alphanumeric product (3.2.1.3.1, pp. 56-57).

(G) 33. Display overlaid set of one to five graphic products (3.2.1.3.2, pp. 57-58).

(G) 34. Display/blank map background topographic data (3.2.1.3.2, p. 58).

(G) 35. Select parameter threshold, phenomena, and change criteria for plot (3.2.1.4.1.1.3, pp. 62-63).

(C) 36. Manage table of reporting stations (3.2.1.4.1.1.4, p. 64).

(G) 37. Create a surface selected parameter plot model (3.2.1.4.1.3.b, p. 65).

(G) 38. Create a UGDF parameter plot model (3.2.1.4.1.3.d, p. 65).

(C) 39. Manage table of isopleth base values and increments (3.2.1.4.3.1, p. 67).

(G) 40. Perform horizontal analysis composite product function (3.2.1.6.1.4, pp. 74-79).

(G) 41. Generate Skew-T, Log-P product (3.2.1.6.2.1, pp. 79-82).

(G) 42. Perform cross-section composite product function (3.2.1.6.2.2.5, pp. 82-88).

(G) 43. Generate continuity workchart (3.2.1.6.3, p. 88).

(G) 44. Generate extrapolation product (3.2.1.6.4, p. 89).

(A) 45. Display derived upper air station parameters (3.2.1.6.5.1, p. 90).

(A) 46. Display derived surface station parameters (3.2.1.6.5.2, p. 90).

(G) 47. Delete a locally-generated graphic product (3.2.1.6.7, p. 90). (Explicit delete of any product - 3.2.1.1.8, p. 48.)

(A) 48. Retrieve station statistics by product type (3.2.1.9.1.1, p. 96).

(A) 49. Hardcopy all station statistics (3.2.1.9.1.1, p. 96).

(A) 50. Reset all station statistics running totals to zero (3.2.1.9.1.1, p. 96).

(A) 51. Transfer Aircraft Accident Investigation (AAI) products to Removable Bulk Storage Media (RMSM) (3.2.1.9.2.2, p. 98).

(A) 52. Hardcopy all (or a subset of) AAI products from disk or RMSM (3.2.1.9.2.2, p. 98).

(C) 53. Annotate or add additional events to event log (3.2.1.9.3, p. 98).

(C) 54. Display event log between selected start and stop times (3.2.1.9.3.1, p. 98).

(C) 55. Hardcopy event log between selected start and stop times (3.2.1.9.3.1, p. 98).

(A) 56. Display complete/partial monthly summary (3.2.1.9.4, p. 99).

(A) 57. Hardcopy complete/partial monthly summary (3.2.1.9.4, p. 99).

(A) 58. Purge old monthly summary (3.2.1.9.4, p. 99).

(A) 59. Perform quality control (QC) review (3.2.1.9.5, p. 99). (Loop, at a selected frequency, through the set of QC products.)

(A) 60. "Correct" products during QC review (3.2.1.9.5, p. 99).

(A) 61. Hardcopy a product that underwent QC review (3.2.1.9.5.3, p. 100).

(A) 62. Purge list of products pending QC review (3.2.1.9.5.3, p. 100).

(C) 63. Manage routing table (3.2.1.10.1.1, p. 101).

(C) 64. Initialize routing function from RMSM (3.2.1.10.1.1, p. 101).

(A/G) 65. Manually override default routing from the Observer Terminal, BWS and SWO/WWO (3.2.1.10.1.2, p. 101).

(A/G) 66. Route a product to a functional area (various sections, pp. 102-105). (This may be an implicit part of the "Display" command.)

(A/G) 67. Route to hardcopy (3.2.1.10.3.6, p. 105). (This may be an implicit part of the alphanumeric print and graphic hardcopy functions.)

(A/G) 68. Route to RMSM (3.2.1.10.3.7, p. 105).

(C) 69. Initialize system (3.2.1.11.1, p. 106).

(C) 70. Checkpoint system (3.2.1.11.2, p. 106).

(C) 71. Perform hot start recovery (3.2.1.11.3.1, p. 106).

(C) 72. Perform warm start recovery (3.2.1.11.3.2, p. 107).

(C) 73. Perform cold start recovery (3.2.1.11.3.3, p. 107).

(A) 74. Prepare Notice to Airmen (NOTAM), including designating type and disposition (3.2.1.12.1, 3.2.1.12.1.1, p. 107; 3.2.1.12.1.1.1, 3.2.1.12.1.2, p. 108).

(A) 75. Transmit/cancel previously created NOTAM (3.2.1.12.1.1.1, p. 108).

(A) 76. Request NOTAMs and Airfield Advisories by ICAO (3.2.1.12.4, p. 109).

(A) 77. Hardcopy NOTAMs and Airfield Advisories (3.2.1.12.4.2, p. 110).

(A) 78. Prepare Airfield Advisory, including designating type (3.2.1.13.1.1, 3.2.1.13.1.2, p. 110).

(C) 79. Delete selected data for transmission after isolation (3.2.1.14.1., p. 111).

(C) 80. Reassign terminal complex functions (3.2.1.14.2, p. 111).

(A/G) 81. Display products and list of products affected by circuit abnormal conditions (3.2.1.14.3, p. 112).

(A/G) 82. Hardcopy products and list of products affected by circuit abnormal conditions (3.2.1.14.3, p. 112).

(A/G) 83. Edit products affected by circuit abnormal conditions (3.2.1.14.3, p. 112).

(A/G) 84. Store edited product; purge abnormally affected product (3.2.1.14.3, p. 113).

(C) 85. Set date and time (3.2.1.17, p. 117).

(A/G) 86. Save/retrieve alphanumeric or graphic "save" product (3.2.1.18.1, p. 117).

(A) 87. Set-aside/retrieve alphanumeric "set-aside" product (3.2.1.18.2, p. 117).

(A/G/C) 88. Provide general prompting assistance (3.2.1.1.5.2, p. 46).

(A/G/C) 89. Display comprehensive list of commands and arguments (3.2.1.1.5.2, p. 46).

(A/G) 90. Display summary list of products and related information (3.2.1.1.8.c, p. 48).

(G) 91. Provide operator initials for locally-generated product titling information (3.2.1.7, p. 90).

(C) 92. Display METWATCH alerting conditions (3.2.1.2.4, p. 52).

<u>KEY</u>

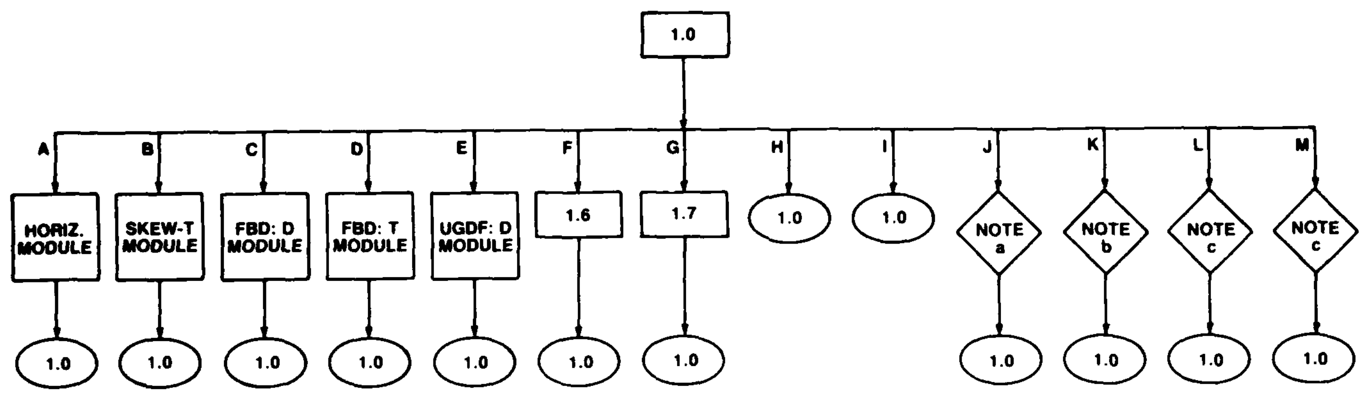
(A) - Alphanumeric category.
(G) - Graphic category.
(C) - Control category.
(A/G) - This requirement should be treated in both the alphanumeric and graphic categories.
(A/G/C) - This requirement should be treated in all three areas.

APPENDIX C

STRAWMAN HIERARCHY OF AWDS GRAPHIC
PROCESSING FUNCTIONS

The graphic processing hierarchy is depicted on 11 diagrams, each representing a portion of the hierarchy. On each diagram, branches correspond to selections made at that particular level in the hierarchy. Numbered square boxes refer to hierarchy modules that are described, along with allowable values, on the pages following each diagram. Numbered circles at the bottom of each chain identify the hierarchy module to which control will be returned following execution of a command. Diamond-shaped boxes refer to notes describing special circumstances that must be considered at that level in the hierarchy. A companion set of assumptions and notes appears at the end of the Appendix.

HIGHEST GRAPHIC HIERARCHY LEVEL



BRANCHES

A - HORIZONTAL COMPOSITE
B - SKEW-T, LOG-P
C - FBD: D X-SECT. COMP.
D - FBD: T X-SECT. COMP.
E - UGDF: D X-SECT. COMP.
F - RUN LOOP/SEQUENCE
G - EXECUTE COMMAND FILE
H - START LOOP SET-UP/MOD.
I - START COMMAND FILE SET-UP/MOD.
J - STOP LOOP SET-UP/MOD.
K - STOP COMMAND FILE SET-UP/MOD.
L - CREATE SFC. PLOT MODEL
M - CREATE UGDF PLOT MODEL

NOTES

a - ENTER LOOP/SEQUENCE NAME
b - ENTER COMMAND FILE NAME AND (IF DESIRED) ASSOCIATION WITH A FUNCTION KEY
c - REQUIRES AN INTERACTIVE PROCEDURE

(1.0)

GRAPHIC FUNCTION

HORIZONTAL COMPOSITE
SKEW-T, LOG-P
FBD: D X-SECT. COMP.
FBD: T X-SECT. COMP.
UGDF: D X-SECT. COMP.
RUN LOOP/SEQUENCE
EXECUTE COMMAND FILE
START LOOP SET-UP/MOD.
START COMMAND FILE SET-UP/MOD.
STOP LOOP SET-UP/MOD.
STOP COMMAND FILE SET-UP/MOD.
CREATE SFC. PLOT MODEL
CREATE UGDF PLOT MODEL

(1.6)

LOOP/SEQUENCE

(Available loops/sequences)

LOOP TIME INTERVAL

5 sec.
6 sec.
7 sec.
8 sec.
9 sec.
10 sec.
11 sec.
12 sec.
13 sec.
14 sec.
15 sec.
16 sec.
17 sec.
18 sec.
19 sec.
20 sec.

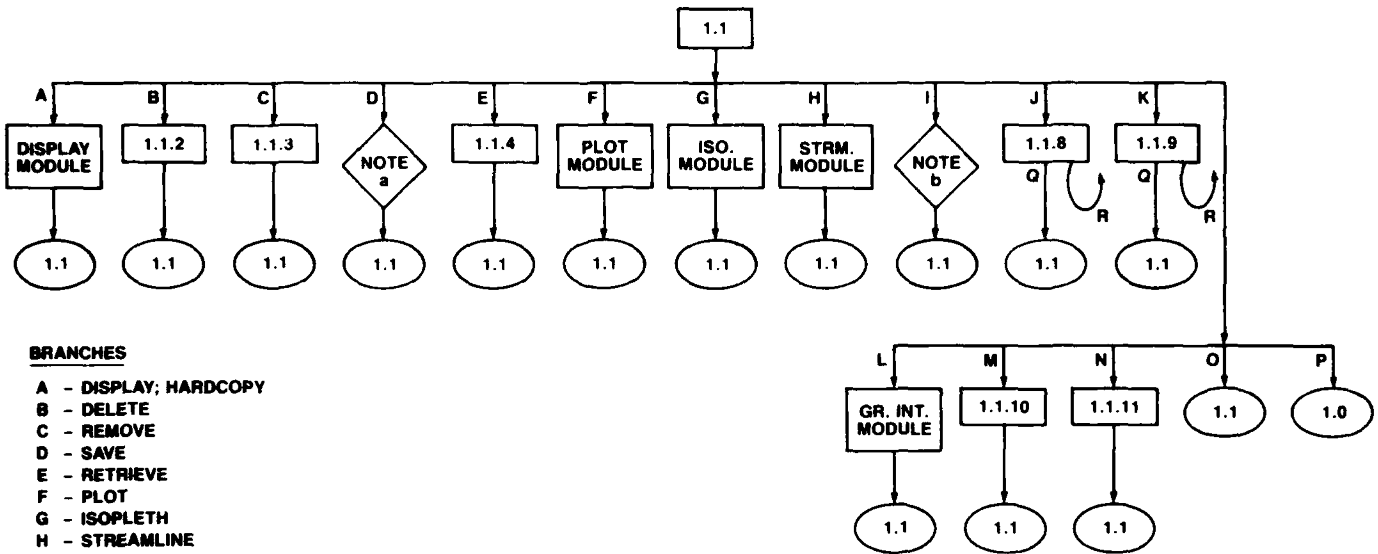
(1.7)

COMMAND FILE

(Available command files)

18-60.804

HORIZONTAL ANALYSIS COMPOSITE MODULE



BRANCHES

A - DISPLAY; HARDCOPY
B - DELETE
C - REMOVE
D - SAVE
E - RETRIEVE
F - PLOT
G - ISOPLETH
H - STREAMLINE
I - EXTRAPOLATION
J - ZOOM A
K - ZOOM B
L - GRAPHIC INTERACTION
M - DISPLAY MAP
N - STORE AND ROUTE
O - CLEAR
P - EXIT
Q - EXIT (FROM ZOOM A OR ZOOM B)
R - ANY OTHER ZOOM A OR ZOOM B OPTION

NOTES

a - ENTER "SAVE" PRODUCT NAME
b - THE INTERACTIVE PROCEDURE DESCRIBED IN NOTE 11 COULD BE USED

(1.1)

HORIZONTAL COMMAND

DISPLAY
HARDCOPY
DELETE
REMOVE
SAVE
RETRIEVE
PLOT
ISOPLETH
STREAMLINE
EXTRAPOLATION
ZOOM A
ZOOM B
GRAPHIC INTERACTION
DISPLAY MAP
STORE AND ROUTE
CLEAR
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.1.2)

LOCAL HORIZ. PRODUCTS

(Available products)

(1.1.3)

REMOVE

(Available numeric
overlays comprising
current composite)

(1.1.4)

RETRIEVE

(Available
horizontal analysis
"save" products)

(1.1.8)

ZOOM A RATIO

1:1
2:1
4:1
8:1
16:1
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.1.9)

<u>ZOOM B RATIO</u>

1:1
2:1
4:1
8:1
16:1
EXIT

<u>MONITOR</u>

MONITOR #1
MONITOR #2

<u>STAT. DISP. PRIORITY</u>

STANDARD
OVERRIDE

<u>UGDF DISP. DENSITY</u>

HIGHEST DISPLAYABLE
EVERY OTHER POINT
EVERY 4TH POINT
EVERY 8TH POINT

(1.1.10)

MAP BACKGROUND

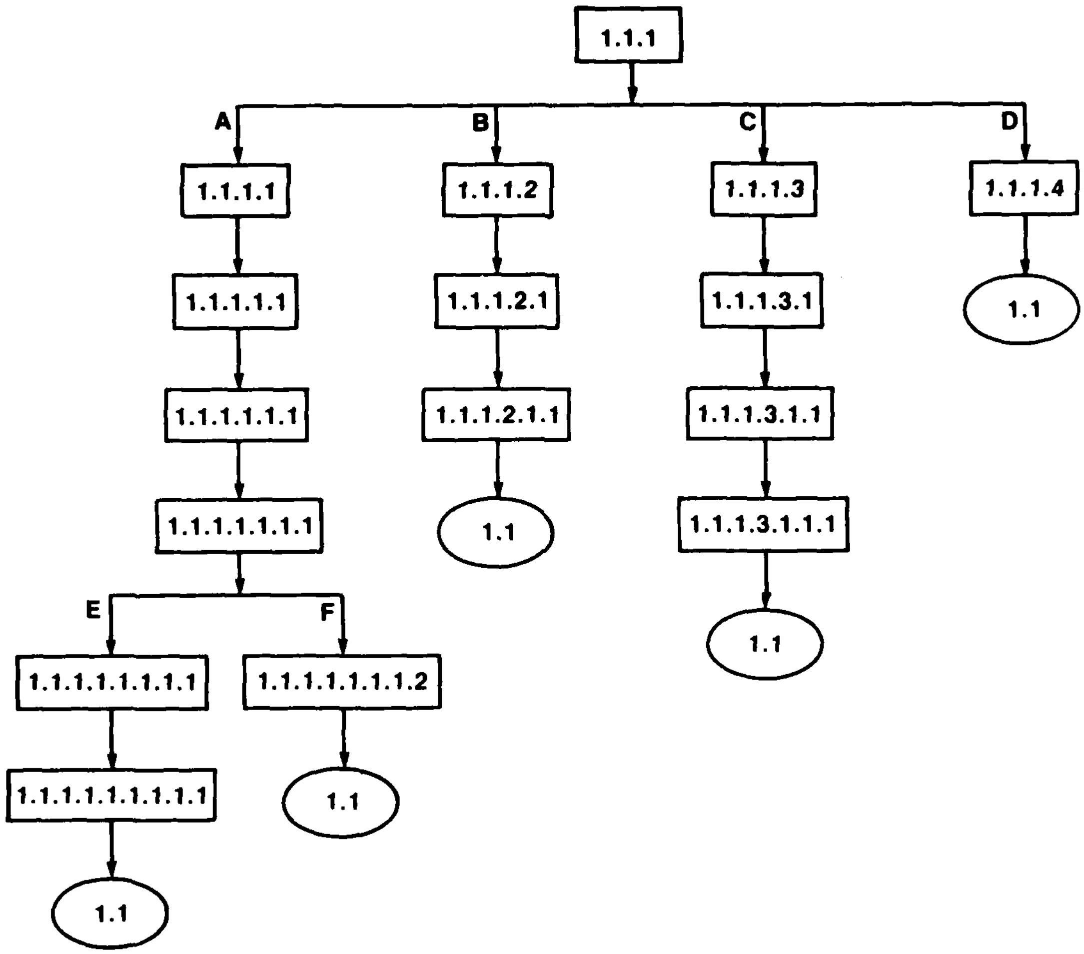
LAWC #1
LAWC #2
LAWC #3
SUBW. N. CENT. U.S.
SUBW. S. CENT. U.S.
SUBW. EAST U.S.
SUBW. N.E. U.S.
SUBW. S.E. U.S.
SUBW. N.E. ATLANTIC
TROP. W. PACIFIC
TROP. E. PACIFIC
TROP. W. HEMISPHERE
TROP. ATLANTIC
TROP. AFRICA
REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.
CONT. N. AMERICA
CONT. ATLANTIC
CONT. N.E. PACIFIC
N. HEMISPHERE U.S.
S. HEMISPHERE

(1.1.11)

ROUTING

(Available functional
areas, including hardcopy)

HORIZONTAL ANALYSIS DISPLAY MODULE



BRANCHES

A - VECTOR GRAPHIC
B - SATELLITE
C - PACKED PIXEL; UNPACKED PIXEL
D - LOCALLY GENERATED
E - SINGLE-LEVEL PARAMETER
F - MULTIPLE-LEVEL PARAMETER OR N/A

IA-69,796

(1.1.1)

DATA INDICATOR

VECTOR GRAPHIC
SATELLITE
PACKED PIXEL
UNPACKED PIXEL
LOCALLY-GENERATED

(1.1.1.1)

DATA DESIGNATOR

WEATHER SUMMARY
CONVECTIVE ANALYSIS
THICKNESS ANALYSIS
LOCAL WIND ANALYSIS
TROP. WEATHER SUMMARY
RADAR ANALYSIS
IAC U/A ANALYSIS
WIND ANALYSIS
ARFOR
U/A & TEMP. FORECAST
EXTENDED FORECASTS
OPERATIONAL FORECAST
IAC-IAC FLEET SURFACE
IAC U/A
MISCELLANEOUS
SWELL
SEA SURFACE TEMP.
MIL. WX. WARNING

(1.1.1.1.1, 1.1.1.3.1)

GEOG. DESIGNATOR

SUBW. N. CENT. U.S.
SUBW. S. CENT. U.S.
SUBW. E. U.S.
SUBW. N.E. U.S.
SUBW. S.E. U.S.
SUBW. N.E. ATLANTIC
TROP. W. PACIFIC
TROP. E. PACIFIC
TROP. W. HEMISPHERE
TROP. ATLANTIC
TROP. AFRICA
REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.
CONT. N. AMERICA
CONT. ATLANTIC
CONT. N.E. PACIFIC
N. HEMISPHERE U.S.
S. HEMISPHERE U.S.

(1.1.1.1.1.1)

<u>BASE TIME/PART #</u>

0 - PART 1
6 - PART 1
12 - PART 1
18 - PART 1
0 - PART 2
6 - PART 2
12 - PART 2
18 - PART 2
0 - PART 3
6 - PART 3
12 - PART 3
18 - PART 3
0 - PART 4
6 - PART 4
12 - PART 4
18 - PART 4

<u>DAY</u>

TODAY
YESTERDAY
DAY BEFORE

(1.1.1.1.1.1.1)

<u>ATM. LEVEL</u>

SURFACE
1000 mb
850 mb
700 mb
600 mb
500 mb
400 mb
300 mb
250 mb
200 mb
150 mb
100 mb
50 mb
TROPOPAUSE
M/L THUNDERSTORMS
M/L CLOUDS & WX.
M/L TURB. & ICING
M/L WINDS & JET
M/L SURF. FEATURES
M/L WX. DEPICTION
M/L UNSPECIFIED
N/A

(1.1.1.1.1.1.1.1)

PARAMETER

MULTIPLE PARAMETER
TOTAL CLOUD AMOUNT
CLOUD BASE
CLOUD TOP
D-VALUE
EQUIV. POT. TEMP.
STREAM FUNCTION
GEOPOTENTIAL HEIGHT
HIGH CLOUD AMOUNT
DIVERGENCE
VORTICITY
STREAMLINES
LOW CLOUD AMOUNT
MIDDLE CLOUD AMOUNT
DEWPOINT DEPRESSION
OMEGA
PRESSURE
QUANT. PRECIP. FORECAST
BND. LAY. D.P. DEP.
SWEAT
TEMPERATURE
U-COMPONENT
V-COMPONENT
PRECIPITABLE WATER
PRIM. PRES. WEATH.
SEC. PRES. WEATH.
TERT. PRES. WEATH.

(1.1.1.1.1.1.1.1.1, 1.1.1.1.1.1.1.2)

<u>FORECAST HOURS/DAYS</u>

0 hours
6 hours
12 hours
18 hours
30 hours
36 hours
1 day
2 days
3 days
4 days
5 days
6 days
7 days
8 days
9 days
10 days

(1.1.1.2, 1.1.1.3)

<u>DATA DESIGNATOR</u>

SATELLITE ANALYSIS
SYN. INT. SAT. CLOUD DAT.
SATELLITE IMAGERY

(1.1.1.2.1)

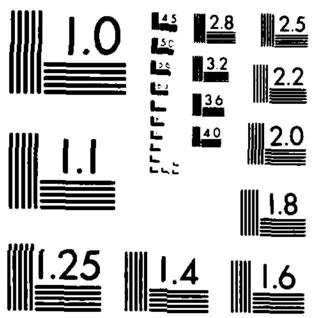
<u>GEOG. DESIGNATOR</u>

SUBW. N. CENT. U.S.
SUBW. S. CENT. U.S.
SUBW. E. U.S.
SUBW. N.E. U.S.
SUBW. S.E. U.S.
SUBW. N.E. ATLANTIC
REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.

AD-A146 033 USE OF PROTOTYPING FOR MAN-MACHINE INTERFACE REQUIREMENTS DEFINITION ON T..(U) MITRE CORP BEDFORD MA C W BENKLEY AUG 84 MTR-9234 ESD-TR-84-178 2/2

UNCLASSIFIED F19628-84-C-0001 F/G 9/2 NL

END
DATE
FILMED
10-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(1.1.1.2.1.1, 1.1.1.3.1.1.1)

<u>VALID TIME</u>

(Available times)

(1.1.1.3.1.1)

<u>ATM. LEVEL</u>

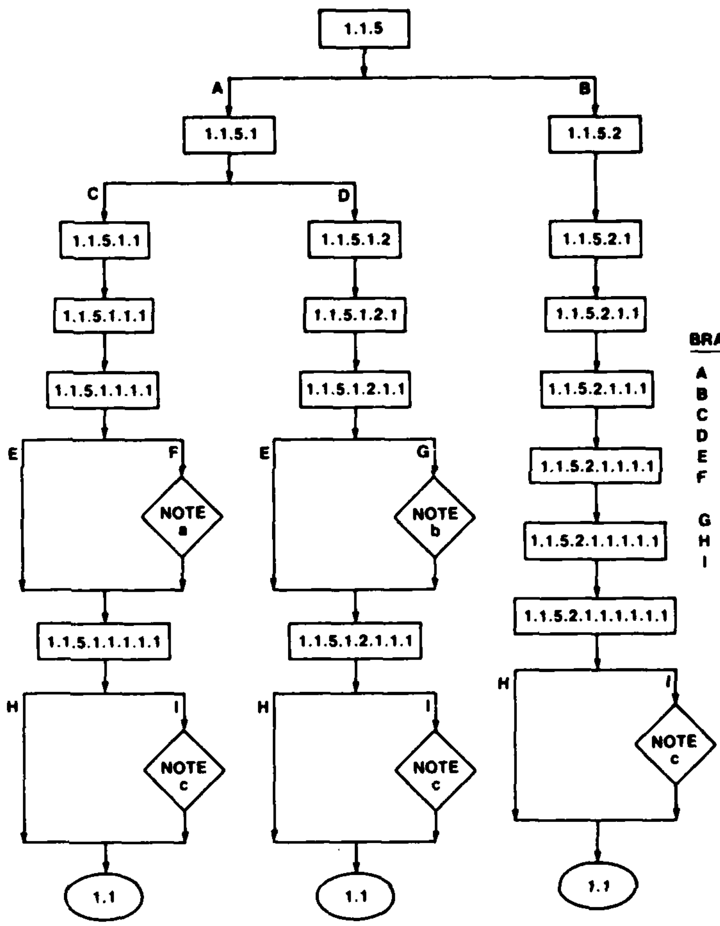
SURFACE
850 mb
700 mb
600 mb
500 mb
400 mb
300 mb
250 mb
200 mb
150 mb
100 mb
50 mb

(1.1.1.4)

<u>LOCAL HORIZ. PRODUCTS</u>

(Available products)

PLOT MODULE



BRANCHES

- A - FORMATTED BINARY
- B - UGDF
- C - HOURLIES; SPECIALS
- D - RAWIN
- E - NONE
- F - *THRESHOLD; PHENOMENA; CHANGE*
- G - THRESHOLD, CHANGE
- H - NO OVERRIDE
- I - DATA OVERRIDE

NOTES

- a - ENTER THRESHOLD, PHENOMENA, AND CHANGE SELECTION CRITERIA
- b - ENTER THRESHOLD AND CHANGE SELECTION CRITERIA
- c - ENTER DATA OVERRIDE INFORMATION

(1.1.5)

DATA INDICATORS

FORMATTED BINARY
PKD. 1/2 MESH
PKD. 1/8 MESH
PKD. 1/64 MESH
UNPKD. WHOLE MESH
UNPKD. 1/2 MESH
UNPKD. 1/8 MESH
UNPKD. 1/64 MESH

(1.1.5.1)

DATA DESIGNATOR

HOURLY AND 1/2 HR.
SPECIALS
RAWIN

(1.1.5.1.1)

SFC PLOT MODEL

(Available surface plot models; help information could identify parameters included)

(1.1.5.1.1.1, 1.1.5.1.2.1)

VALID TIMES

(Available times)

(1.1.5.1.1.1.1)

SELECTION CRITERIA

NONE
THRESHOLD SELECTION
PHENOMENA SELECTION
CHANGE SELECTION

(1.1.5.1.1.1.1.1, 1.1.5.1.2.1.1.1,
1.1.5.2.1.1.1.1.1.1)

DATA OVERRIDE

DATA OVERRIDE
NO OVERRIDE

(1.1.5.1.2)

ATMOS. LEVEL

1000 mb
850 mb
700 mb
500 mb
400 mb
300 mb
200 mb
150 mb
100 mb
50 mb
30 mb
10 mb

(1.1.5.1.2.1.1)

SELECTION CRITERIA

NONE
THRESHOLD SELECTION
CHANGE SELECTION

(1.1.5.2)

DATA DESIGNATOR

WEATHER SUMMARY
CONVECTIVE ANALYSIS
GRID. T. AND D.P. DEP.
THICKNESS ANALYSIS
LOCAL WIND ANALYSIS
SATELLITE ANALYSIS
IAC U/A ANALYSIS
VERT. MOTION ANALYSIS
WIND ANALYSIS
MISCELLANEOUS
ARFOR
U/A WIND AND T. FORECAST
EXTENDED FORECASTS
GRID POINT FORECASTS
OPERATIONAL FORECASTS
IAC UPPER AIR
VERT. MOTION PROGNOSIS
SEA SURFACE TEMPERATURE
SYN. INT. OF SAT. CL. DATA

(1.1.5.2.1)

GEOGRAPHIC DESIGNATOR

REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.

(1.1.5.2.1.1)

BASE TIME/PART #

0 - PART 1
6 - PART 1
12 - PART 1
18 - PART 1
0 - PART 2
6 - PART 2
12 - PART 2
18 - PART 2
0 - PART 3
6 - PART 3
12 - PART 3
18 - PART 3
0 - PART 4
6 - PART 4
12 - PART 4
18 - PART 4

DAY

TODAY
YESTERDAY
DAY BEFORE

(1.1.5.2.1.1.1)

ATMOSPHERIC LEVEL

1000 mb
850 mb
700 mb
500 mb
300 mb
200 mb

(1.1.5.2.1.1.1.1)

FORECAST HOURS/DAYS

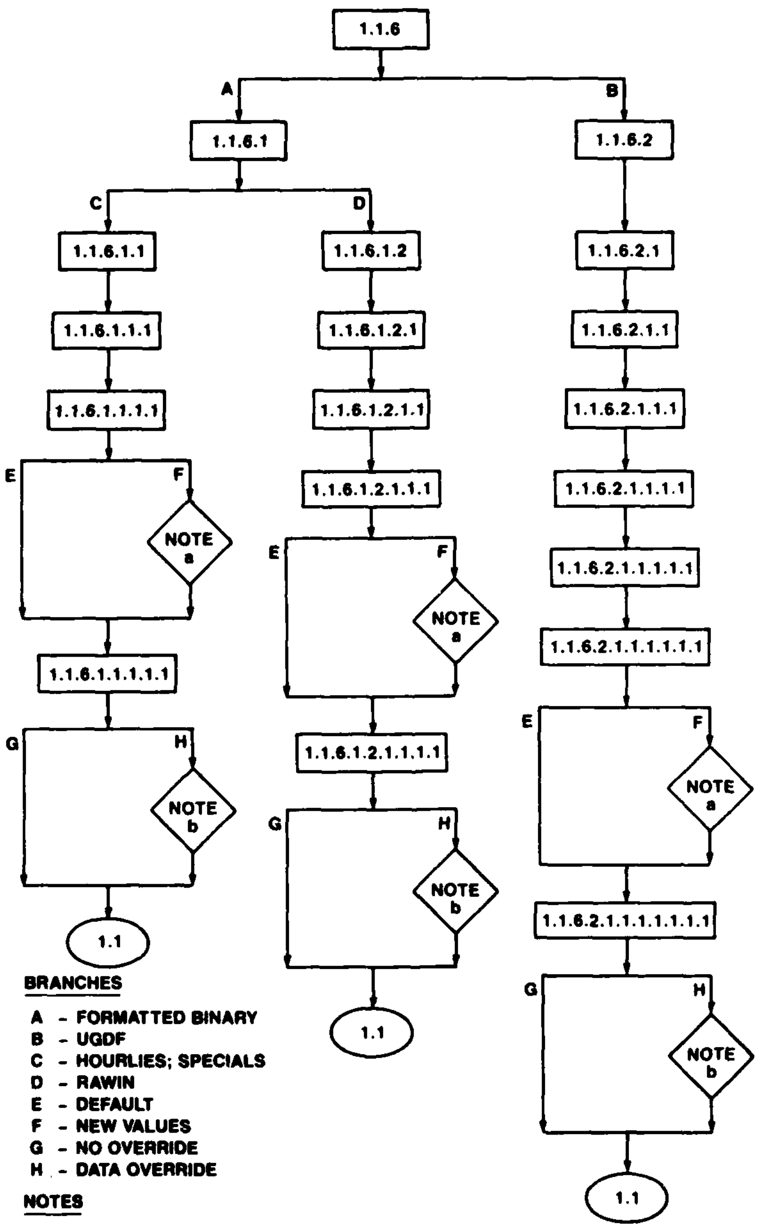
0 hours
6 hours
12 hours
18 hours
30 hours
36 hours
1 day
2 days
3 days
4 days
5 days
6 days
7 days
8 days
9 days
10 days

(1.1.5.2.1.1.1.1.1)

UGDF PLOT MODEL

(Available UGDF plot models; help information could identify parameters included)

ISOPLETH MODULE



BRANCHES

A - FORMATTED BINARY
B - UGDF
C - HOURLIES; SPECIALS
D - RAWIN
E - DEFAULT
F - NEW VALUES
G - NO OVERRIDE
H - DATA OVERRIDE

NOTES

a - ENTER ISOPLETH LEVELS
b - ENTER DATA OVERRIDE INFORMATION

(1.1.6)

DATA INDICATORS

FORMATTED BINARY
PKD. 1/2 MESH
PKD. 1/8 MESH
PKD. 1/64 MESH
UNPKD. WHOLE MESH
UNPKD. 1/2 MESH
UNPKD. 1/8 MESH
UNPKD. 1/64 MESH

(1.1.6.1)

DATA DESIGNATOR

HOURLY AND 1/2 HR.
SPECIALS
RAWIN

(1.1.6.1.1)

SURFACE PARAMETER

ALTIMETER SETTING
BARO. TENDENCY
DEWPOINT TEMPERATURE
SEA LEVEL PRESSURE
TEMPERATURE
VISIBILITY
WIND SPEED
RELATIVE HUMIDITY
ADVECTED FIELD
ADVECTION
ADD
SUBTRACT
U-COMPONENT
V-COMPONENT

(1.1.6.1.1.1, 1.1.6.1.2.1)

VALID TIME

(Available times)

(1.1.6.1.1.1.1, 1.1.6.1.2.1.1.1,
1.1.6.2.1.1.1.1.1.1)

ISOPLETH LEVELS

DEFAULT
(Help information could
identify default bases
and increments)
NEW VALUES

(1.1.6.1.1.1.1.1, 1.1.6.1.2.1.1.1.1,
1.1.6.2.1.1.1.1.1.1.1)

DATA OVERRIDE

DATA OVERRIDE
NO OVERRIDE

(1.1.6.1.2)

U/A PARAMETER

DEWPOINT DEPRESSION
GEOPOTENTIAL HEIGHT
TEMPERATURE
WIND SPEED
RELATIVE HUMIDITY
D-VALUES
ADVECTED FIELD
ADVECTION
ADD
SUBTRACT
U-COMPONENT
V-COMPONENT

(1.1.6.1.2.1.1)

ATMOSPHERIC LEVEL

1000 mb
850 mb
700 mb
500 mb
400 mb
300 mb
200 mb
150 mb
100 mb
50 mb
30 mb
10 mb

(1.1.6.2)

DATA DESIGNATOR

WEATHER SUMMARY
CONVECTIVE ANALYSIS
GRID. T. AND D.P. DEP.
THICKNESS ANALYSIS
LOCAL WIND ANALYSIS
SATELLITE ANALYSIS
IAC U/A ANALYSIS
VERT. MOTION ANALYSIS
WIND ANALYSIS
MISCELLANEOUS
ARFOR
U/A WIND AND T. FORECAST
EXTENDED FORECASTS
GRID POINT FORECASTS
OPERATIONAL FORECASTS
IAC UPPER AIR
VERT. MOTION PROGNOSIS
SEA SURFACE TEMPERATURE
SYN. INT. OF SAT. CL. DATA

(1.1.6.2.1)

GEOGRAPHIC DESIGNATOR

REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.

(1.1.6.2.1.1)

UGDF MNEMONIC

D-VALUE
EQUIV. POT. TEMP.
STREAM FUNCTION
GEOPOTENTIAL HEIGHT
DIVERGENCE
VORTICITY
DEWPOINT DEPRESSION
OMEGA
QUANT. PRECIP. FORECAST
BOUND. LAY. DEW. DEP.
SWEAT
TEMPERATURE
U-COMPONENT
V-COMPONENT
RELATIVE HUMIDITY
WIND SPEED
ADVECTED FIELD
ADVECTION
ADD
SUBTRACT

(1.1.6.2.1.1.1)

BASE TIME/PART #

0 - PART 1
6 - PART 1
12 - PART 1
18 - PART 1
0 - PART 2
6 - PART 2
12 - PART 2
18 - PART 2
0 - PART 3
6 - PART 3
12 - PART 3
18 - PART 3
0 - PART 4
6 - PART 4
12 - PART 4
18 - PART 4

DAY

TODAY
YESTERDAY
DAY BEFORE

(1.1.6.2.1.1.1.1)

ATMOSPHERIC LEVEL

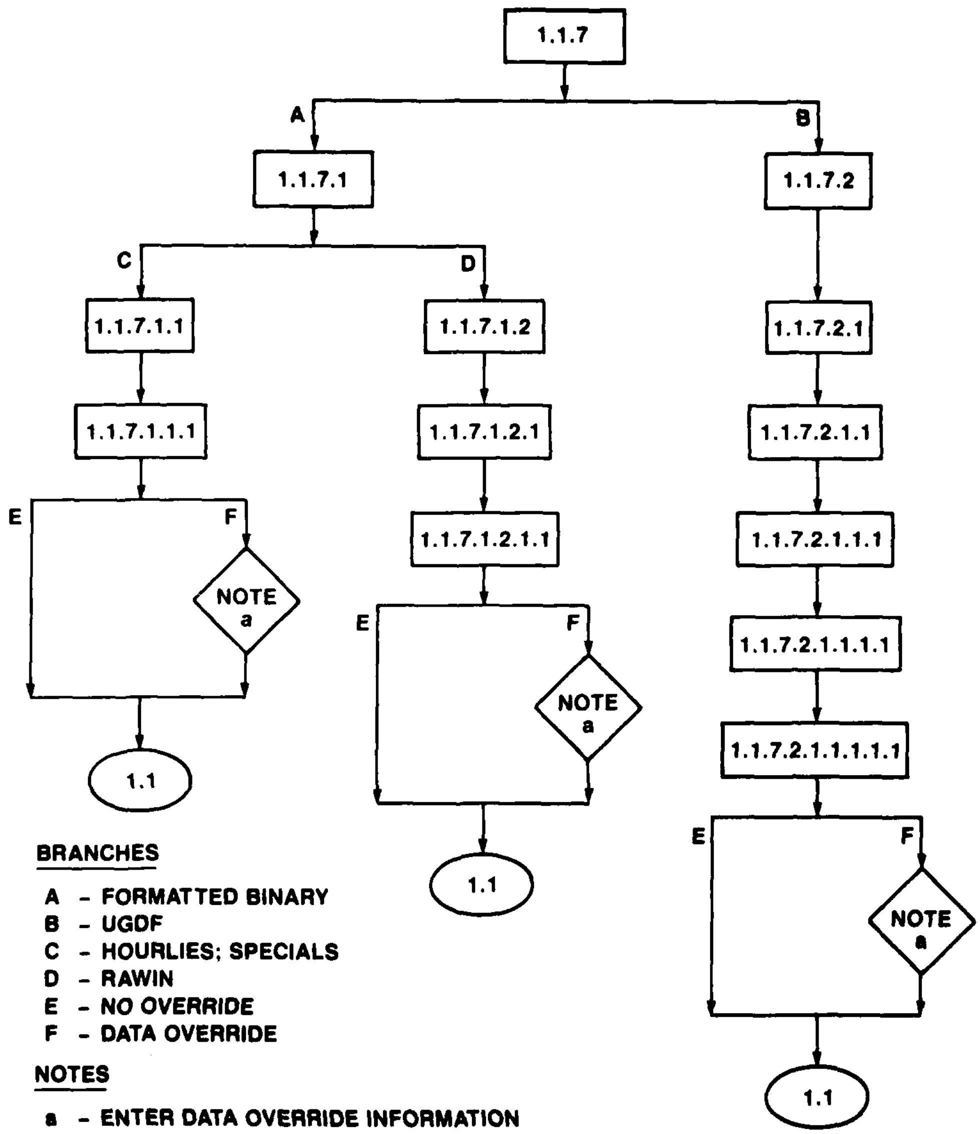
1000 mb
850 mb
700 mb
500 mb
300 mb
200 mb

(1.1.6.2.1.1.1.1.1)

<u>FORECAST HOURS/DAYS</u>

0 hours
6 hours
12 hours
18 hours
30 hours
36 hours
1 day
2 days
3 days
4 days
5 days
6 days
7 days
8 days
9 days
10 days

STREAMLINE MODULE



BRANCHES

A - FORMATTED BINARY
B - UGDF
C - HOURLIES; SPECIALS
D - RAWIN
E - NO OVERRIDE
F - DATA OVERRIDE

NOTES

a - ENTER DATA OVERRIDE INFORMATION

IA-69,801

(1.1.7)

DATA INDICATORS

FORMATTED BINARY
PKD. 1/2 MESH
PKD. 1/8 MESH
PKD. 1/64 MESH
UNPKD. WHOLE MESH
UNPKD. 1/2 MESH
UNPKD. 1/8 MESH
UNPKD. 1/64 MESH

(1.1.7.1)

DATA DESIGNATOR

HOURLY AND 1/2 HR.
SPECIALS
RAWIN

(1.1.7.1.1, 1.1.7.1.2.1)

VALID TIME

(Available times)

(1.1.7.1.1.1, 1.1.7.1.2.1.1,
1.1.7.2.1.1.1.1.1)

DATA OVERRIDE

DATA OVERRIDE
NO OVERRIDE

(1.1.7.1.2)

ATMOSPHERIC LEVEL

1000 mb
850 mb
700 mb
500 mb
400 mb
300 mb
200 mb
150 mb
100 mb
50 mb
30 mb
10 mb

(1.1.7.2)

DATA DESIGNATOR

WEATHER SUMMARY
CONVECTIVE ANALYSIS
GRID. T. AND D.P. DEP.
THICKNESS ANALYSIS
LOCAL WIND ANALYSIS
SATELLITE ANALYSIS
IAC U/A ANALYSIS
VERT. MOTION ANALYSIS
WIND ANALYSIS
MISCELLANEOUS
ARFOR
U/A WIND AND T. FORECAST
EXTENDED FORECASTS
GRID POINT FORECASTS
OPERATIONAL FORECASTS
IAC UPPER AIR
VERT. MOTION PROGNOSIS
SEA SURFACE TEMPERATURE
SYN. INT. OF SAT. CL. DATA

(1.1.7.2.1)

GEOGRAPHIC DESIGNATOR

REG. WINDOW CONUS
REG. WINDOW E. U.S.
REG. WINDOW N. U.S.

(1.1.7.2.1.1)

BASE TIME/PART #

0 - PART 1
6 - PART 1
12 - PART 1
18 - PART 1
0 - PART 2
6 - PART 2
12 - PART 2
18 - PART 2
0 - PART 3
6 - PART 3
12 - PART 3
18 - PART 3
0 - PART 4
6 - PART 4
12 - PART 4
18 - PART 4

DAY

TODAY
YESTERDAY
DAY BEFORE

(1.1.7.2.1.1.1)

ATMOSPHERIC LEVEL

1000 mb
850 mb
700 mb
500 mb
300 mb
200 mb

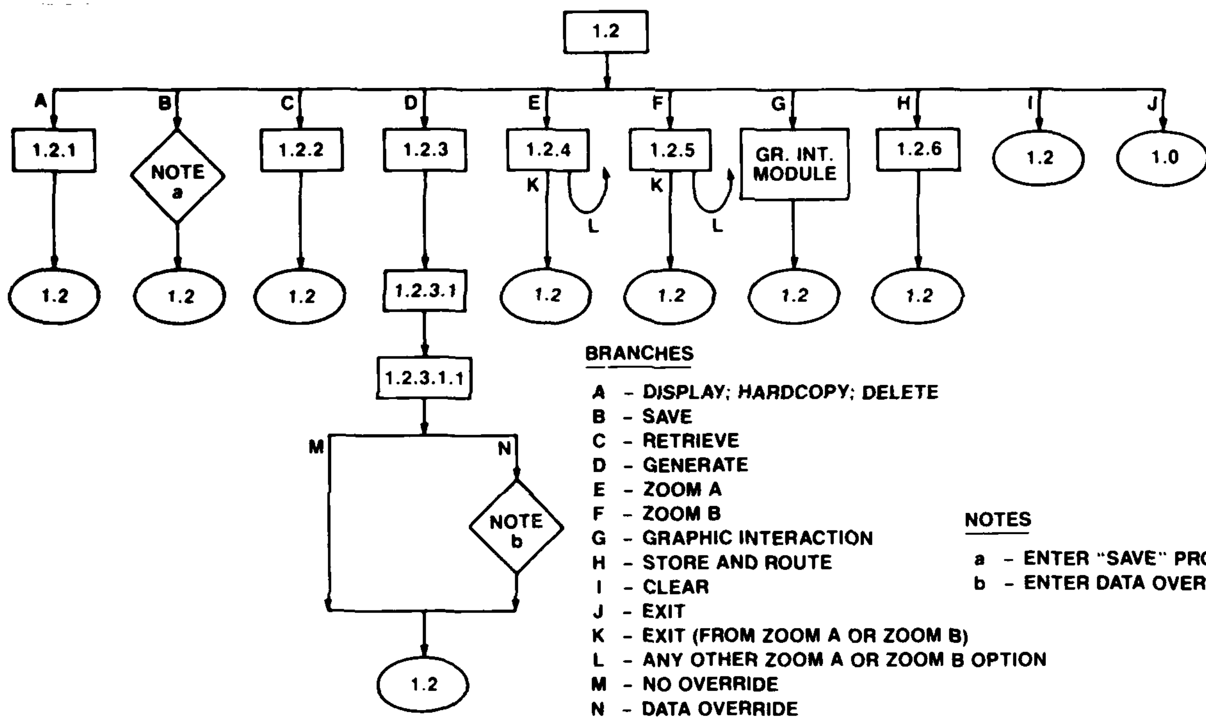
(1.1.7.2.1.1.1.1)

FORECAST HOURS/DAYS

0 hours
6 hours
12 hours
18 hours
30 hours
36 hours
1 day
2 days
3 days
4 days
5 days
6 days
7 days
8 days
9 days
10 days

IA-69.805

SKEW-T, LOG-P MODULE



BRANCHES

A - DISPLAY; HARDCOPY; DELETE
B - SAVE
C - RETRIEVE
D - GENERATE
E - ZOOM A
F - ZOOM B
G - GRAPHIC INTERACTION
H - STORE AND ROUTE
I - CLEAR
J - EXIT
K - EXIT (FROM ZOOM A OR ZOOM B)
L - ANY OTHER ZOOM A OR ZOOM B OPTION
M - NO OVERRIDE
N - DATA OVERRIDE

NOTES

a - ENTER "SAVE" PRODUCT NAME
b - ENTER DATA OVERRIDE INFORMATION

(1.2)

SKEW-T COMMAND

DISPLAY
HARDCOPY
DELETE
SAVE
RETRIEVE
GENERATE
ZOOM A
ZOOM B
GRAPHIC INTERACTION
STORE AND ROUTE
CLEAR
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.2.1)

SKEW-T PRODUCTS

(Available products)

(1.2.2)

RETRIEVE

(Available
Skew-T, Log-P
"save" products)

(1.2.3)

STATION

(Up to 100)

(1.2.3.1)

OF PREVIOUS TIMES

0
1
2

(1.2.3.1.1)

DATA OVERRIDE

DATA OVERRIDE
NO OVERRIDE

(1.2.4)

ZOOM A RATIO

1:1
2:1
4:1
8:1
16:1
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.2.5)

ZOOM B RATIO

1:1
2:1
4:1
8:1
16:1
EXIT

MONITOR

MONITOR #1
MONITOR #2

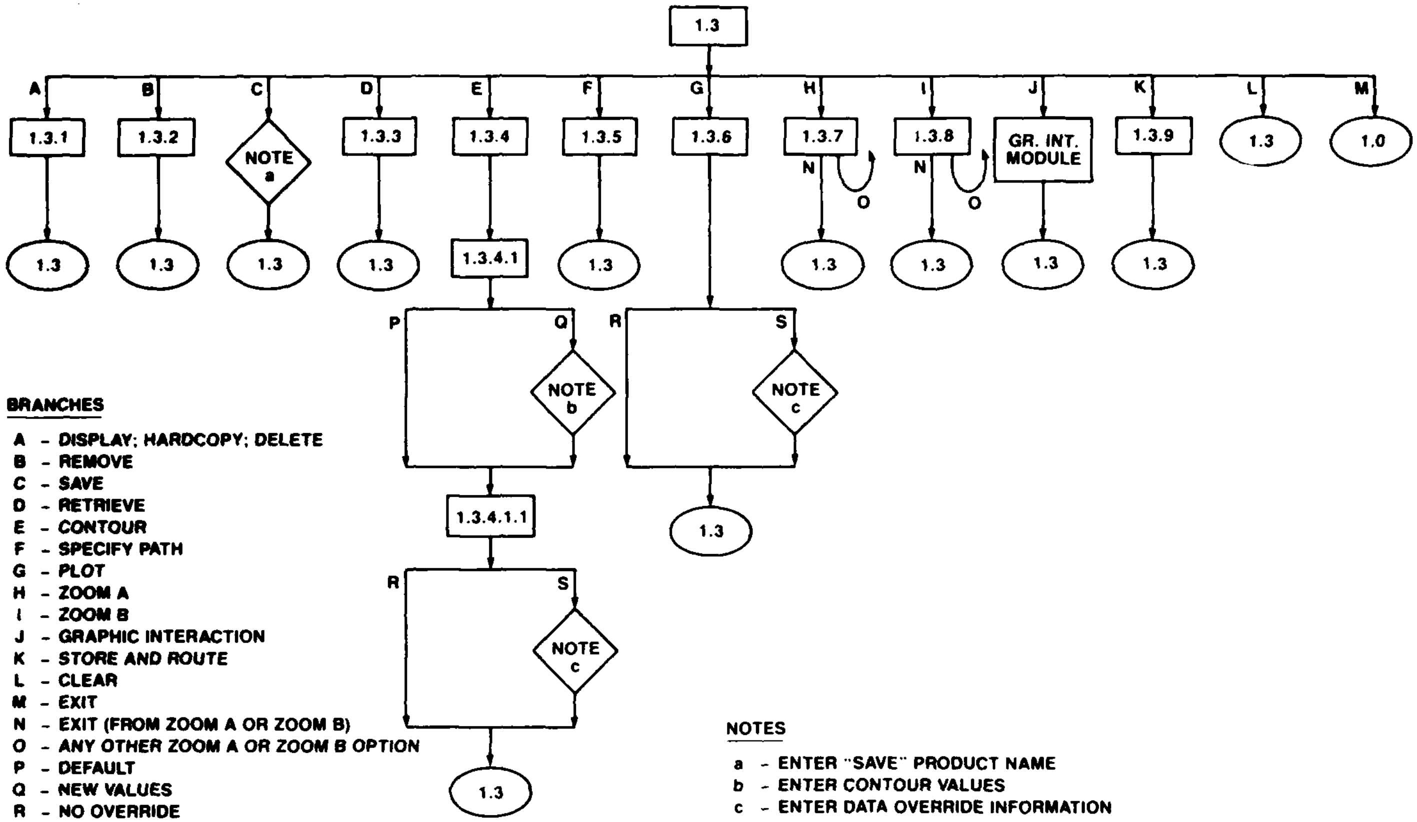
(1.2.6)

ROUTING

(Available functional
areas, including hardcopy)

18-00.007

FBD: DISTANCE CROSS SECTION MODULE



BRANCHES

A - DISPLAY; HARDCOPY; DELETE
B - REMOVE
C - SAVE
D - RETRIEVE
E - CONTOUR
F - SPECIFY PATH
G - PLOT
H - ZOOM A
I - ZOOM B
J - GRAPHIC INTERACTION
K - STORE AND ROUTE
L - CLEAR
M - EXIT
N - EXIT (FROM ZOOM A OR ZOOM B)
O - ANY OTHER ZOOM A OR ZOOM B OPTION
P - DEFAULT
Q - NEW VALUES
R - NO OVERRIDE
S - DATA OVERRIDE

NOTES

a - ENTER "SAVE" PRODUCT NAME
b - ENTER CONTOUR VALUES
c - ENTER DATA OVERRIDE INFORMATION

(1.3)

CROSS SECTION COMMAND

DISPLAY
HARDCOPY
DELETE
REMOVE
SAVE
RETRIEVE
CONTOUR
SPECIFY PATH
PLOT
ZOOM A
ZOOM B
GRAPHIC INTERACTION
STORE AND ROUTE
CLEAR
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.3.1)

CROSS SECTION PRODUCTS

(Available products)

(1.3.2)

REMOVE

(Available numeric
overlays comprising
current composite)

(1.3.3)

RETRIEVE

(Available
"save" products valid
for cross section type
and path)

(1.3.4)

CONTOUR

POTENTIAL TEMP.
EQUIV. POT. TEMP.
D-VALUES
VERT. WIND SHEAR
RELATIVE HUMIDITY
MIXING RATIO
TEMPERATURE
DEWPOINT DEPRESSION
WIND SPEED

(1.3.4.1)

CONTOUR LEVELS

DEFAULT <par. name>
(Help information could
identify default bases,
increments, and units)
NEW VALUES

(1.3.4.1.1, 1.3.6)

<u>DATA OVERRIDE</u>

DATA OVERRIDE
NO OVERRIDE

(1.3.5)

<u>STATIONS</u>

(Up to 100)

<u>VALID TIME</u>

0 hours
6 hours
12 hours
18 hours

<u>DAY</u>

TODAY
YESTERDAY
DAY BEFORE

(1.3.7)

<u>ZOOM A RATIO</u>

1:1
2:1
4:1
8:1
16:1
EXIT

<u>MONITOR</u>

MONITOR #1
MONITOR #2

(1.3.8)

ZOOM B RATIO

1:1
2:1
4:1
8:1
16:1
EXIT

MONITOR

MONITOR #1
MONITOR #2

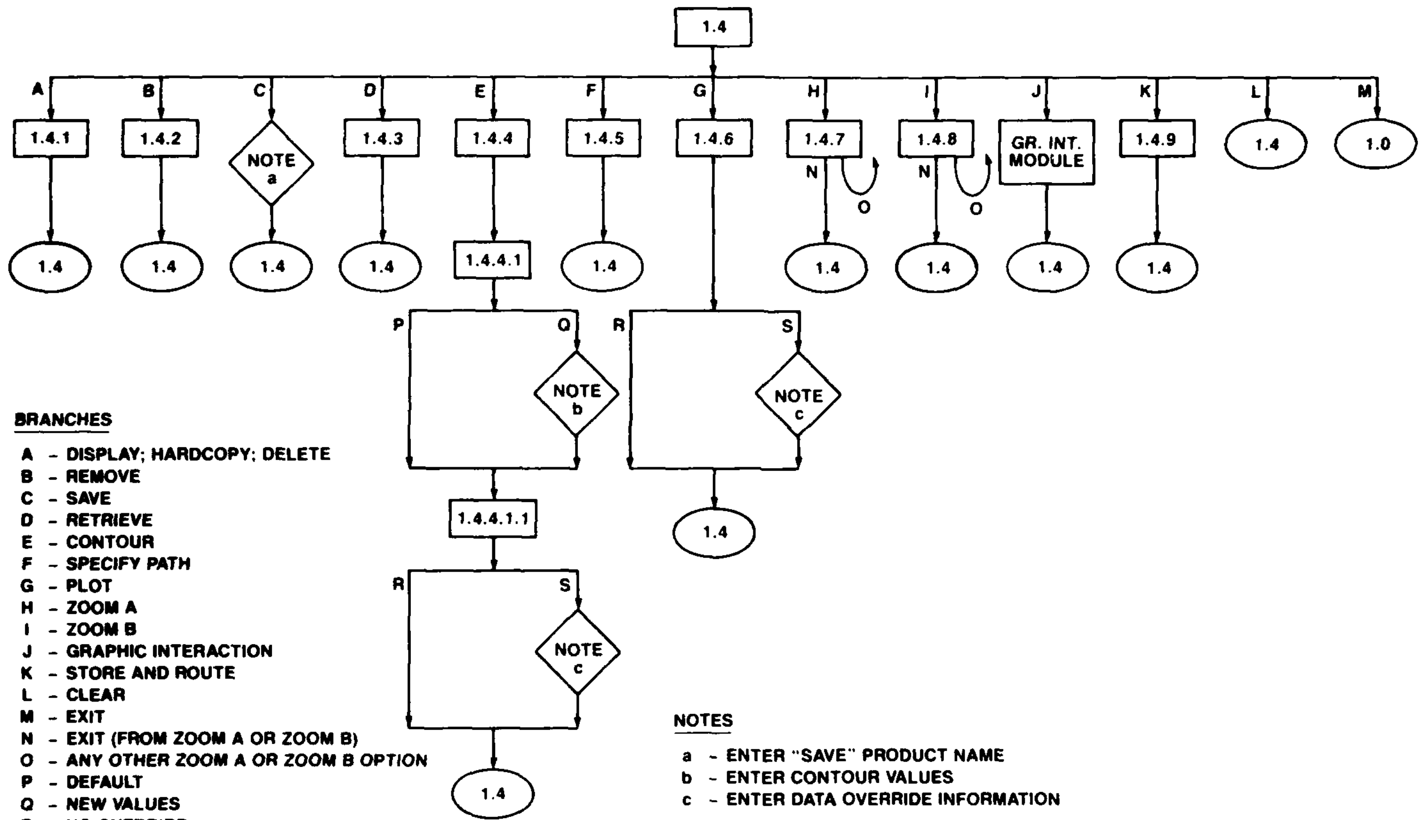
(1.3.9)

ROUTING

(Available functional areas,
including hardcopy)

IS-69.000

FBD: TIME CROSS SECTION MODULE



BRANCHES

A – DISPLAY; HARDCOPY; DELETE
B – REMOVE
C – SAVE
D – RETRIEVE
E – CONTOUR
F – SPECIFY PATH
G – PLOT
H – ZOOM A
I – ZOOM B
J – GRAPHIC INTERACTION
K – STORE AND ROUTE
L – CLEAR
M – EXIT
N – EXIT (FROM ZOOM A OR ZOOM B)
O – ANY OTHER ZOOM A OR ZOOM B OPTION
P – DEFAULT
Q – NEW VALUES
R – NO OVERRIDE
S – DATA OVERRIDE

NOTES

a – ENTER "SAVE" PRODUCT NAME
b – ENTER CONTOUR VALUES
c – ENTER DATA OVERRIDE INFORMATION

(1.4)

CROSS SECTION COMMAND

DISPLAY
HARDCOPY
DELETE
REMOVE
SAVE
RETRIEVE
CONTOUR
SPECIFY PATH
PLOT
ZOOM A
ZOOM B
GRAPHIC INTERACTION
STORE AND ROUTE
CLEAR
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.4.1)

CROSS SECTION PRODUCTS

(Available products)

(1.4.2)

REMOVE

(Available numeric
overlays comprising
current composite)

(1.4.3)

<u>RETRIEVE</u>

(Available "save" products valid
for cross section type and path)

(1.4.4)

<u>CONTOUR</u>

POTENTIAL TEMP.
EQUIV. POT. TEMP.
D-VALUES
VERT. WIND SHEAR
RELATIVE HUMIDITY
MIXING RATIO
TEMPERATURE
DEWPOINT DEPRESSION
WIND SPEED

(1.4.4.1)

<u>CONTOUR LEVELS</u>

DEFAULT <par. name>
(help information could
identify default bases,
increments, and units)
NEW VALUES

(1.4.4.1.1, 1.4.6)

<u>DATA OVERRIDE</u>

DATA OVERRIDE
NO OVERRIDE

(1.4.5)

<u>STATION</u>

(Up to 100)

<u># OF PREVIOUS TIMES</u>

1
2
3

(1.4.7)

<u>ZOOM A RATIO</u>

1:1
2:1
4:1
8:1
16:1
EXIT

<u>MONITOR</u>

MONITOR #1
MONITOR #2

(1.4.8)

ZOOM B RATIO

1:1
2:1
4:1
8:1
16:1
EXIT

MONITOR

MONITOR #1
MONITOR #2

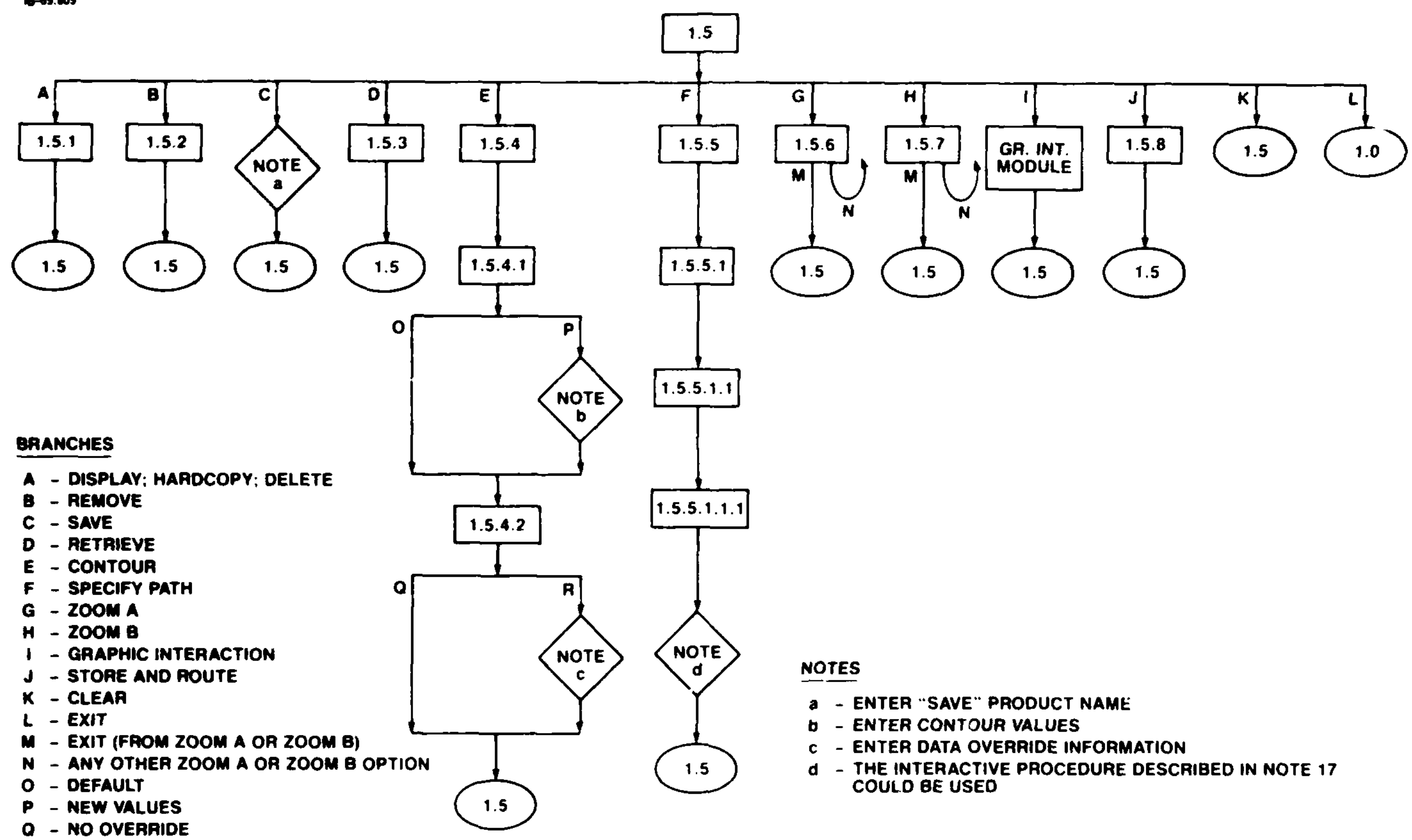
(1.4.9)

ROUTING

(Available functional areas,
including hardcopy)

18-69.809

UGDF: DISTANCE CROSS SECTION MODULE



BRANCHES

A - DISPLAY; HARDCOPY; DELETE
B - REMOVE
C - SAVE
D - RETRIEVE
E - CONTOUR
F - SPECIFY PATH
G - ZOOM A
H - ZOOM B
I - GRAPHIC INTERACTION
J - STORE AND ROUTE
K - CLEAR
L - EXIT
M - EXIT (FROM ZOOM A OR ZOOM B)
N - ANY OTHER ZOOM A OR ZOOM B OPTION
O - DEFAULT
P - NEW VALUES
Q - NO OVERRIDE
R - DATA OVERRIDE

NOTES

a - ENTER "SAVE" PRODUCT NAME
b - ENTER CONTOUR VALUES
c - ENTER DATA OVERRIDE INFORMATION
d - THE INTERACTIVE PROCEDURE DESCRIBED IN NOTE 17 COULD BE USED

(1.5)

CROSS SECTION COMMAND

DISPLAY
HARDCOPY
DELETE
REMOVE
SAVE
RETRIEVE
CONTOUR
SPECIFY PATH
ZOOM A
ZOOM B
GRAPHIC INTERACTION
STORE AND ROUTE
CLEAR
EXIT

MONITOR

MONITOR #1
MONITOR #2

(1.5.1)

<u>CROSS SECTION PRODUCTS</u>

(Available products)

(1.5.2)

<u>REMOVE</u>

(Available numeric
overlays comprising
current composite)

(1.5.3)

<u>RETRIEVE</u>

(Available "save" products
valid for cross section type
and path)

(1.5.4)

<u>CONTOUR</u>

POTENTIAL TEMP.
EQUIV. POT. TEMP.
D-VALUES
VERT. WIND SHEAR
RELATIVE HUMIDITY
MIXING RATIO
TEMPERATURE
DEWPOINT DEPRESSION
WIND SPEED

(1.5.4.1)

CONTOUR LEVELS

DEFAULT <par. name>
(help information could
identify bases, increments,
and units)
NEW VALUES

(1.5.4.2)

DATA OVERRIDE

DATA OVERRIDE
NO OVERRIDE

(1.5.5)

<u>REGIONAL WINDOW</u>

CONUS
EAST U.S.
NORTH U.S.

<u>MESH SIZE</u>

WHOLE
HALF
EIGHTH
SIXTY-FOURTH

(1.5.5.1)

<u>DATA DESIGNATOR</u>

WEATHER SUMMARY
CONVECTIVE ANALYSIS
GRID T. AND D.P. DEP
THICKNESS ANALYSIS
LOCAL WIND ANALYSIS
SATELLITE ANALYSIS
IAC U/A ANALYSIS
VERTICAL MOTION ANALYSIS
WIND ANALYSIS
MISCELLANEOUS
ARFOR
U/A WIND AND T. FORECAST
EXTENDED FORECASTS
GRID POINT FORECASTS
OPERATIONAL FORECASTS
IAC UPPER AIR
VERTICAL MOTION PROGNOSIS
SEA SURFACE TEMPERATURE
SYN. INT. OF SAT. CL. DATA

(1.5.5.1.1)

BASE TIME/PART #

0 - PART 1
6 - PART 1
12 - PART 1
18 - PART 1
0 - PART 2
6 - PART 2
12 - PART 2
18 - PART 2
0 - PART 3
6 - PART 3
12 - PART 3
18 - PART 3
0 - PART 4
6 - PART 4
12 - PART 4
18 - PART 4

DAY

TODAY
YESTERDAY
DAY BEFORE

(1.5.5.1.1.1)

FORECAST HOURS/DAYS

0 hours
6 hours
12 hours
18 hours
30 hours
36 hours
1 day
2 days
3 days
4 days
5 days
6 days
7 days
8 days
9 days
10 days

(1.5.6)

<u>ZOOM A RATIO</u>

1:1
2:1
4:1
8:1
16:1
EXIT

<u>MONITOR</u>

MONITOR #1
MONITOR #2

(1.5.7)

<u>ZOOM B RATIO</u>

1:1
2:1
4:1
8:1
16:1
EXIT

<u>MONITOR</u>

MONITOR #1
MONITOR #2

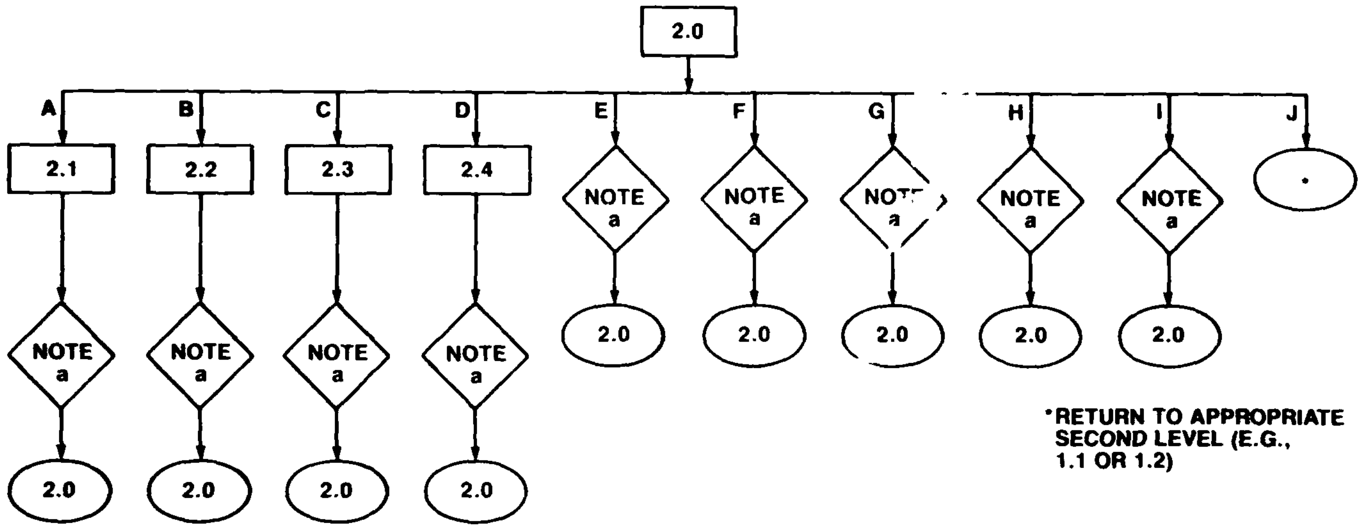
(1.5.8)

<u>ROUTING</u>

(Available functional areas,
including hardcopy)

IA-69,806

GRAPHIC INTERACTION MODULE



*RETURN TO APPROPRIATE SECOND LEVEL (E.G., 1.1 OR 1.2)

BRANCHES

A – ADD SYMBOL
B – ADD SYMBOLIC LINE
C – ADD CHARACTER
D – ADD TEXT
E – DELETE FEATURE
F – HIGHLIGHT FEATURE
G – RELOCATE FEATURE
H – MODIFY FEATURE
I – POLYGON FILL
J – EXIT

NOTE

a – AN INTERACTIVE PROCEDURE IS NECESSARY

(2.0)

GRAPHIC INTERACTION

ADD SYMBOL
ADD SYMBOLIC LINE
ADD CHARACTER
ADD TEXT
DELETE FEATURE
HIGHLIGHT FEATURE
RELOCATE FEATURE
MODIFY FEATURE
POLYGON FILL
EXIT

MONITOR

MONITOR #1
MONITOR #2

(2.1)

ADD SYMBOL

(Specify symbol)

(2.2)

ADD SYMBOLIC LINE

(Specify symbolic line)

(2.3)

ADD CHARACTER

(Specify character,
color, character size,
and line width)

(2.4)

ADD TEXT

(Input text string;
specify color,
character size,
and line width)

(3.0)

ADVECTION INTERVAL

1 hour
2 hours
3 hours
4 hours
5 hours
6 hours
7 hours
8 hours
9 hours
10 hours
11 hours
12 hours

ASSUMPTIONS AND NOTES

General

(1) The system should not permit the operator to store an exact copy of an externally-generated product (i.e., an externally-generated product that has not been interacted with, or overlayed with, another product).

(2) The STORE option could either return the user to the top of the hierarchy (module 1.0) or to the appropriate place in the next level in the hierarchy (e.g., module 1.1 or 1.2). There are probably advantages to each implementation, but one consistent choice should be adopted.

(3) Hierarchy module 1.1.10 lists 22 map backgrounds that might be appropriate for a Base Weather Station (BWS) in the Northeastern United States. The hierarchy module for the product geographic designator (e.g., 1.1.1.1.1, 1.1.1.3.1, etc.) lists only those map backgrounds that are appropriate for the given product type. For Uniform Gridded Data Field (UGDF) products, only regional window geographic designators apply. For satellite products, only regional window and satellite subwindow geographic designators apply. For vector graphic and pixel products, satellite subwindow and Local Area Workchart (LAWC) geographic designators do not apply.

(4) In order to obviate the need to remove and totally regenerate products when bad data is encountered, the data override option is placed at the bottom of each appropriate branch in the hierarchy, and cannot be invoked until the product is displayed. At that time, noting bad data, execution of the data override option would cause the system to remove the erroneous product from the display, and regenerate a corrected copy. Actual specification of override information could be as follows:

   a) Allow the user to specify the parameter of interest from the appropriate parameter hierarchy module (surface Formatted Binary Data (FBD) parameter, upper air FBD parameter, or UGDF parameter);

   b) Display the appropriate data (station parameters or UGDF grid point parameters) at the proper map or cross section path coordinates and allow the user to pick the bad value;

c) Enter the new (override) parameter value as a text string; and

d) Repeat this procedure as many times as necessary to override all bad data.

5) According to Specification Section 3.2.1.16.2, an average of 904 products components will be locally-generated every 24 hours. This corresponds to generating one graphic product component every one minute and 35 seconds, a rate which appears to be excessive even for an AWDS with multiple Staff Weather Officer/Wing Weather Officer (SWO/WWO) functional areas. Nevertheless, the magnitude of this number suggests that it may be difficult to keep track of locally-generated products in the system, especially in view of the fact that locally-generated product names are selected by the operator. A hierarchy of locally-generated product types might have to be enforced in order to fac'litate retrieval.

(6) When more than one "menu" appears for a given hierarchy module, a menu-driven implementation could accommodate the multiple menus on a single menu page. For other implementations, however, additional hierarchical levels are needed.

(7) It is assumed that product retention criteria is based upon product categories, not individual products themselves. This function is included in the control category.

(8) The requirements for manual routing of graphic (and, probably alphanumeric) products within AWDS are confusing; all graphic products should already be available at all functional areas that support graphic processing. For the strawman hierarchy, it is assumed that manual routing of externally-generated products is not needed. Requirements for routing of locally-generated products are interpreted as a means by which the operator, after storing a product, can specify related routing information - whatever its use.

(9) Ideally, the operator should be able to isopleth and contour multiple parameters in a single invocation of the appropriate product generation function, but the strawman hierarchy does not provide this capability because it is not known how many product identifier fields must be respecified in order to uniquely identify each additional parameter. As an example, the need for certain product identifier fields (such as the data designator) in guaranteeing product uniqueness should be verified. In addition, the flexibility needed to permit

isoplething and contouring of parameters with different base times, forecast times, atmospheric levels, geographic areas, and product types may limit the usefulness of this capability.

Horizontal Analysis Products

(10) The requirement to display topographic map data could be handled by allowing the user to switch back and forth between the two map display modes whenever a map appears on the screen.

(11) The extrapolation function could be carried out as follows:

a) The operator uses a DISPLAY or ISOPLETH command to display a horizontal analysis product;

b) The operator invokes the extrapolation function and picks the feature to be extrapolated;

c) The system temporarily displays (possibly as monochrome overlays) two selected earlier versions of the product, and allows the user to pick the feature of interest; and

d) The system computes and displays the extrapolated position of the feature of interest.

(12) The ADVECTION parameter option for the isopleth function could be carried out as follows:

a) Remain at the appropriate parameter hierarchy module (1.1.6.1.1, 1.1.6.1.2, or 1.1.6.2.1.1), this time disallowing now irrelevant parameter options (ADVECTION, ADVECTED FIELD, and ADD/SUBTRACT), and allow the user to specify the advection parameter of interest; and

b) Continue to the next appropriate module of the hierarchy (1.1.6.1.1.1, 1.1.6.1.2.1, or 1.1.6.2.1.1.1).

(13) The ADVECTED FIELD parameter option for the isopleth function could be carried out as follows:

a) Remain at the appropriate parameter hierarchy (1.1.6.1.1, 1.1.6.1.2, or 1.1.6.2.1.1), this time disallowing now irrelevant parameter options (ADVECTION, ADVECTED FIELD, and ADD/SUBTRACT), and allow the user to specify the advected field parameter of interest;

b) Allow the user to specify the desired advection time interval (hierarchy module 3.0); and

c) Continue to the next appropriate module in the hierarchy (1.1.6.1.1.1, 1.1.6.1.2.1, or 1.1.6.2.1.1.1).

(14) The ADD/SUBTRACT parameter option might be difficult to implement if a substantial amount of generality is to be accommodated. For example, the user may want to perform the ADD/SUBTRACT option for: a) different atmospheric levels (e.g., GPH (500 mb) minus GPH (1000 mb)); b) different FBD file times (e.g., TMP (1200 GMT) minus TMP (0000 GMT)); c) different UGDF base and forecast times (e.g., TMP (Base time = 0000 GMT, Forecast interval = 24 hours) minus TMP (Base time = 1200 GMT, Forecast interval = 12 hours)); d) different data types (e.g., a comparison of predicted UGDF field with an observed FBD field); and, possibly e) different parameters entirely (e.g., TMP minus DPT). If all but the last option are to be accommodated, a possible way to implement the ADD/SUBTRACT parameter option is:

a) Remain at the appropriate parameter hierarchy module (1.1.6.1.1, 1.1.6.1.2, or 1.1.6.2.1.1), this time disallowing now irrelevant parameter options (ADVECTION, ADVECTED FIELD, and ADD/SUBTRACT), and allow the user to specify the name of the first add/subtract parameter of interest;

b) Cycle through to hierarchy module 1.1.6.1.1.1.1.1, 1.1.6.1.2.1.1.1.1, or 1.1.6.2.1.1.1.1.1.1.1, allowing the user to specify additional information about the first add/subtract parameter; and

c) Return to hierarchy module 1.1.6, and cycle through the entire isopleth module (omitting the ISOPLETH LEVEL, but not the DATA OVERRIDE hierarchy level), allowing the user to specify the second add/subtract parameter.

The system should prevent the user from attempting to add/subtract incompatible parameters (e.g., temperature and pressure).

(15) For the horizontal analysis and cross section composite product functions (hierarchy modules 1.1, 1.3, 1.4, and 1.5), the appropriate product background (map background or appropriate cross section path outline) must appear on the display screen before display or product generation functions can be executed. The product produced by the command will be

"overlayed" with the existing display information if a mutually compatible product background already appears on the screen; otherwise, an error will occur. An existing display can be cleared by the CLEAR command, or cleared and replaced by a new product background via a DISPLAY MAP or SELECT PATH command. In the latter case, in a multitasking environment, the system could then proceed to display the new product background concurrently with operator-entry of subsequent commands.

Vertical Analysis Products

(16) The "specify path" branch will provide information such as "stations" and "valid time" for the FBD: Distance vs. Log-P cross section, "station" and "number of previous file times" for the FBD: Time vs. Log-P cross section, and the D, AA, TT, First-i, and Second-E product identifiers for the UGDF: Distance vs. Log-P cross section.

(17) The selection of endpoints for UGDF cross sections is probably best carried out, after an input is given for hierarchy module 1.5.5 (REGIONAL WINDOW/MESH SIZE), by displaying the selected map, superposed with a grid of the selected mesh, and enabling the user to interactively select the grid endpoints.

(18) The requirement for operator input of "valid time" for the Skew-T, Log-P chart and the FBD: Time vs. Log-P cross section is interpreted as a provision to indicate how many previous file times are to be included with the current file time in generating the appropriate product.

Loops, Sequences, and Command Files

(19) It is assumed that loops and sequences will be composed entirely of vector graphic and/or raster scan products.

(20) It is assumed that command files will be composed of either all graphic or all alphanumeric commands. Further, for a graphic command file, the commands included should all be valid for the same product type. If this criteria is not met, the display screen would clear when product types were switched (e.g, if Skew-T, Log-P commands are issued following Horizontal Analysis Product commands).

(21) For consistency, the construction and modification of loops and sequences and command files should follow the same procedures the operator would use to individually execute the commands to be included. The strawman design accommodates

this by the use of START and STOP commands. All commands issued between successive START and STOP commands will become part of the loop, sequence, or command file being created.

(22) There is no need to make any distinction between the creation of a loop and the creation of a sequence - loops and sequences differ only in the way they are run. Provided that the loop time interval is specified by the LOOP/SEQUENCE module (1.6), all other degrees of freedom for running loops and sequences could be accommodated by three buttons allowing: 1) forward sequencing; 2) reverse sequencing; and 3) start/stop looping.

(23) Upon completion of execution of a command file, the system should place the user at the hierarchy module that is the root for the type of graphic product created. For example, if a Formatted Binary: Time vs. Log-P cross section is generated by a command file, the user should be placed at hierarchy module 1.4 (CROSS SECTION COMMAND) following completion of execution of the command file. This feature will allow the user to proceed to perform other functions, such as graphic interaction, on the displayed product.

Zoom

(24) Because there is no requirement to store a product at a zoom A ratio other than 1:1, the EXIT option of the zoom A hierarchy level should automatically return the product to the 1:1 zoom A ratio. By contrast, because a product can indeed be stored at a zoom B ratio other than 1:1, the EXIT option of the zoom B menu should not alter the zoom B ratio in effect.

(25) A strawman concept for the zoom B prioritization for horizontal analysis products is that the "default" reporting station prioritization and the "highest displayable" UGDF plot prioritization are invoked when the product is created. The user should proceed to the zoom B hierarchy level to subsequently adjust the prioritizations for any zoom ratio (including 1:1).

LIST OF ACRONYMS

AA	Geographic Designator (product identifier field)
AAI	Aircraft Accident Investigation
AFCC	Air Force Communications Command (AFCC)
AFOS	Automation of Field Operations and Services
AGDS	AWDS Graphic Development System
ANSI	American National Standards Institute
ARQ	Automatic Response to Query
ATC	Air Traffic Control
AWDS	Automated Weather Distribution System
AWIS	Automated Weather Information Systems
AWS	Air Weather Service
BWS	Base Weather Station
CAD/CAM	Computer-Aided Design/Computer-Aided Manufacture
CB9	Cumulonimbus With Anvil
C^3I	Command, Control, Communications, and Intelligence
CDR	Critical Design Review
D	Data Type Indicator (product identifier field)
F	File Indicator (product identifier field)
FA	Functional Area
FBD	Formatted Binary Data
FCF	Flight Control Facility
FO	Flight Operations
FSED	Full-Scale Engineering Development
GF	Ground Fog
GKS	Graphical Kernel System
GMT	Greenwich Mean Time
GPH	Geopotential Height
ICAO	International Civil Aviation Organization
ICD	Interface Control Drawing
ISO	International Standards Organization
LAWC	Local Area Workchart
McIDAS	Man-Computer Interactive Data Access System
MMI	Man-Machine Interface
NOTAM	Notice to Airmen
NWS	National Weather Service
PROFS	Prototype Regional Observing & Forecasting Service

LIST OF ACRONMYNS (continued)

QC	Quality Control
RMSM	Removable Magnetic Storage Media
SDR	System Design Review
SG	Snow Grains
SOW	Statement of Work
SRR	System Requirements Review
STS	Specialty Training Standard
SWO/WWO	Staff Weather Officer/Wing Weather Officer
TBS	Severe Turbulence
TMP	Temperature
TSS	Tropical Storm - Southern Hemisphere
TT	Data Type Subcategory (product identifier field)
UGDF	Uniform Gridded Data Field
WPH	Shower During the Past Hour

ATE

LME